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ABSTRACT

Included are descriptions of activities of each of the 12 laboratories in the National Research Council of Canada, including background information and a summary of the studies (research) and results. The 12 laboratories in the NRCL are the following: Atlantic Regional Laboratory, Biochemistry Laboratory, Division of Biology, Division of Building Research, Division of Chemistry, Division of Mechanical Engineering, National Aeronautical Establishment, Prairie Regional Laboratory, Division of Physics, Radio and Electrical Engineering Division and Astrophysics Branch, and the London Office. Also included are the lists of publications authored by the staff of each laboratory and a directory of staff. (PR)

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NRCL-70

review of the activities of the laboratories

1970

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THE NATIONAL RESEARCH COUNCIL OF CANADA

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review of the activities of the laboratories

1970

THE NATIONAL RESEARCH COUNCIL OF CANADA

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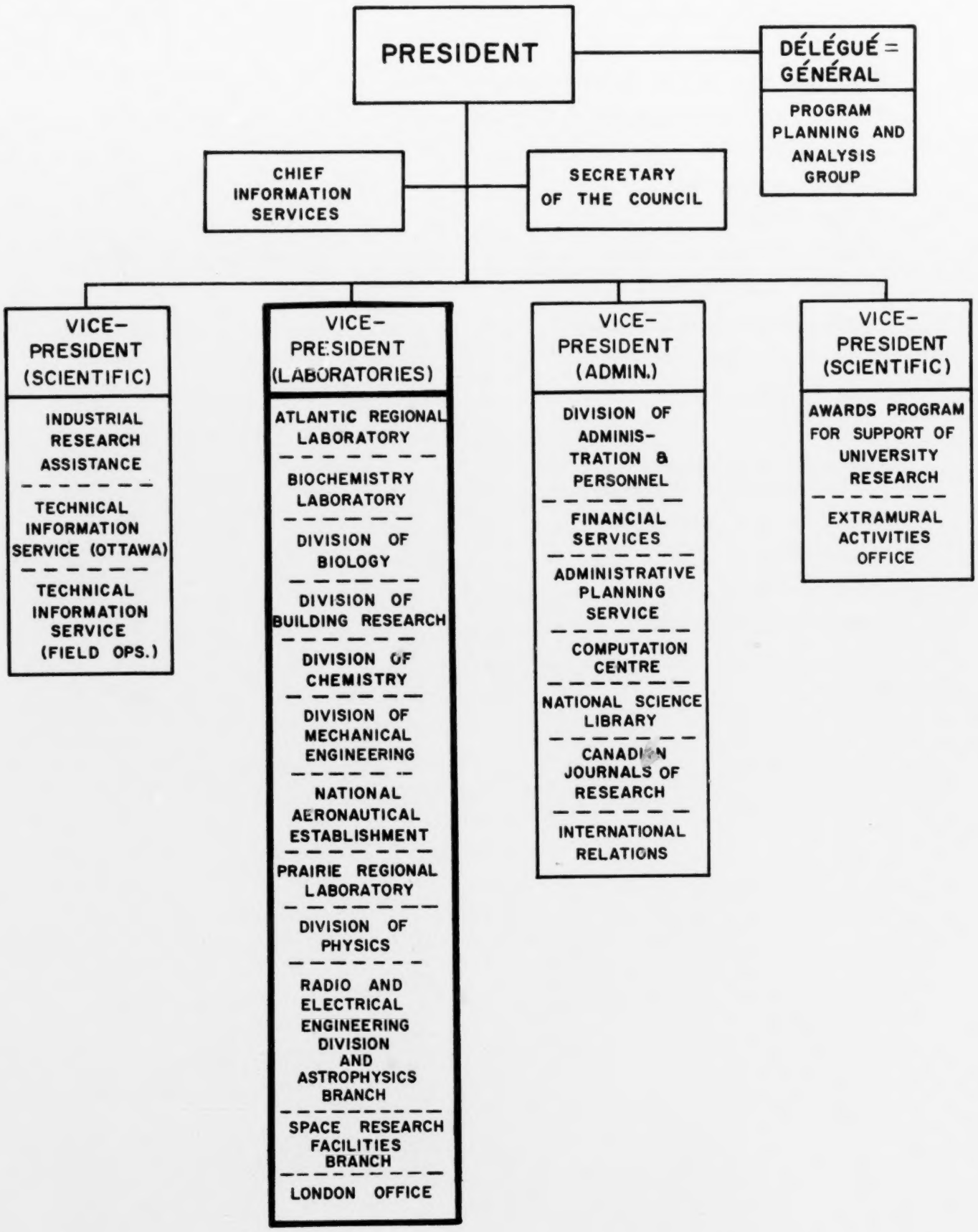

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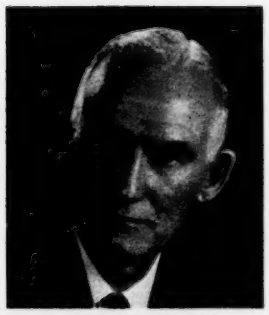

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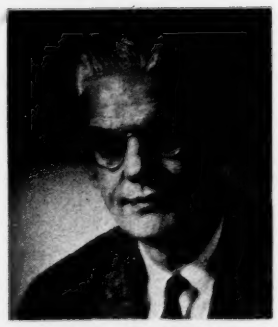

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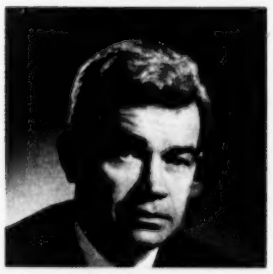

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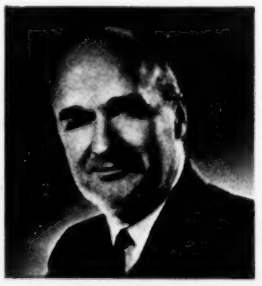

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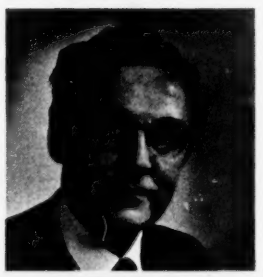

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FOREWORD FROM THE VICE-PRESIDENT (LABORATORIES)

Introducing NRCL-70

For many years, up to 1968, the annual NRC REVIEW provided an overview of all NRC activities, including the laboratories, university grants and scholarships, associate committees, the industrial assistance program, etc. The REVIEW did not appear in 1969—an incidental casualty, perhaps, of the sweeping re-organization of the overall NRC structure described in the Report of the President for 1968-69. Its absence from the scene was noted with regret by many readers.

This new publication, NRCL-70, is designed to revive those portions of the old REVIEW which dealt with the activities of the NRC Laboratories. If our readers approve it will be followed next year by NRCL-71, and so on. Your comments on its contents and format, addressed to the Editor, Mr. Ron Shuttleworth, would be much appreciated. Similar annual reviews may be produced by other sectors of the NRC complex—or they may not. Assuming that you were inclined to put pen to paper in response to our invitation to comment on NRCL-70, perhaps you might also care to express your views about the desirability or otherwise of once again publishing all of the annual reviews of NRC's activities under one cover.

As you scan through the pages that follow you will notice quite a wide variation in length and style among the Divisional contributions. Other than to offer a few simple guidelines the Editor has not attempted to press the accounts into a common mold for this edition. This is an experiment —future latitude will depend to some extent on reader reactions. The list of reports and publications and the staff listings have been included in response to user requests, but we may have omitted other information which you would like to see presented.

Organizational Changes

Some internal realignments have been made in the organization of the laboratory divisions in the past two years. While these changes and the reasons therefore have been reported in more detail elsewhere, notably in the President's Report for 1968–69 and 1969–70, it may be useful to recapitulate just the highlights here.

One new division was created in 1968, known as the Biochemistry Laboratory, by assembling selected groups from three existing divisions, Pure Chemistry, Biosciences, and Pure Physics. The remainder of the Division of Biosciences was coalesced with the Division of Radiation Biology to form the new Division of Biology. The Division of Pure Physics and the Division of Applied Physics were combined into one Division of Physics. Similarly, the new Division of Chemistry was formed by amalgamating the Division of Pure Chemistry and the Division of Applied Chemistry.

NRCL's ranks were recently augmented by the transfer of the astronomical staff who were formerly with the Dominion Observatories Branch of the Department of Energy, Mines and Resources. All governmental astronomy is now the responsibility of the Astrophysics Branch, which is attached to the Radio and Electrical Engineering Division. Two other new additions to the NRCL family, acquired by internal transfers, are the Space Research Facilities Branch and the NRC London Office.

Several retirements at the senior level have taken place in the past two years which should be noted here. The retirement of Dr. W. H. Cook, Director of Biosciences, occurred, coincidentally, about the time of the creation of the new Division of Biology. Dr. Cook's right-hand man, Dr. N. E. Gibbons, continued as the Assistant Director of the new Division until recently, when he resigned in order to pursue a private consulting career. Both gentlemen, in fact, continue to be actively involved in biological affairs in Canada.

The founder and guiding genius of the Division of Building Research, Dr. Robert F. Legget, relinquished the Director's chair last year, but his keen interest in the nation-wide problems of the building industry is undiminished as evidenced, for one example, by his continuing connection with the National Building Code. Dr. L. E. Howlett, former Director of the Division of Applied Physics,

is now trying his hand at industrial enterprises. The Head of the old Division of Pure Chemistry, Dr. J. A. Morrison, resigned to accept an important post at McMaster University, though he maintains his connections with many aspects of NRC affairs. Following his retirement as Associate Director of the Division of Applied Physics, Dr. D. C. Rose accepted a position at Carleton University.

Dr. G. Herzberg's official retirement date as Director of the Division of Pure Physics happened to coincide with the creation of the new Division of Physics. However, Dr. Herzberg was persuaded to continue his researches within the new Division, with the special title "Distinguished Research Scientist".

As a natural result of these reorganizations and retirements some new names have appeared at the heads of the rosters of many of the Divisions, as the reader may ascertain by consulting the divisional reports which follow.

The Board of Directors of the NRCL

A Board of Directors of the National Research Council Laboratories, consisting of divisional directors and branch heads, has been formed to deal with the business of running the complex and multidisciplinary conglomerate that is the NRCL. The Chairman of the Board is the Vice-President (Laboratories) of NRC, and the Deputy Chairman is elected by the Board itself, on a rotational basis. For 1970, the Deputy Chairman is Dr. Ira E. Puddington. Mr. P. J. Choquette serves as the continuing Secretary.

The coordination of interdisciplinary projects, involving close cooperation between two or more Divisions, figures prominently in the deliberations of the Board of Directors. Occasionally, such projects may be originated formally at the Boardroom table but more often the initial stimulus arises elsewhere. Many of the most effective collaborations have blossomed at the level of the working scientist, perhaps over a cup of coffee. Others begin when one Division undertakes a problem for industry or a government department and finds that the aid of another Division would be either helpful or essential. Some examples of such cooperative efforts are to be found in the divisional reviews which follow.

Particular mention may be made here of one such project on instrumentation development which has recently been initiated and which involves all the Divisions. The development of many kinds of instrumentation to the patentable stage and beyond is by no means a novel experience for the NRCL. Indeed, several Divisions have for years regarded such work as part of their normal stock-in-trade, as the files of Canadian Patents and Development Limited will testify. No doubt, though, many a potentially marketable invention in the field of laboratory instrumentation has not been recognized as such. The Délégué-Général's staff have suggested recently that some form of task force to ferret out these ideas whenever they may arise in the NRCL would be very useful. In accepting and implementing the suggestion the Board of Directors has created a special sub-committee entrusted with the job of first identifying such ideas and then of exploring ways and means to ensure that the necessary development can be carried out. It promises to be an interesting experiment, though its success will depend to a very great extent on the interface with the entrepreneurs in the marketplace. One may build a better mousetrap only to find that the customer prefers to use Warfarin!

The Board of Directors does not spend all of its time on day-to-day administrative and operational matters. As the President of NRC has expressed it in his 1969–70 Report, far better than I could, ". . . . Not the least of the Board's responsibilities will be the formulation of long-range policies and plans, based on a continuous analysis and assessment of the laboratories' internal programs and their interfaces with universities, industry, and other government departments. In this task it is anticipated that the advice and assistance, both of the Divisional Advisory Boards and of the Délégué-Général and his staff, will be indispensable. Nor could viable plans for NRCL be effectively developed without the closest cooperation between the Board of Directors and the Vice-Presidents in charge of industrial and university programs respectively".

Although they do not appear formally on the NRCL organization chart there is no question that the people in the Division of Administration and in Financial Services, to mention only two examples, are regarded both as close friends and as honorary members of the Board, since they are inextricably interwoven with the Board's business in matters of personnel, purchasing, budgeting, and other common administrative arrangements. The Board takes this opportunity to acknowledge its debt to Dr. K. F. Tupper, Vice-President (Administration), who has brought his broad experience, tactful understanding, and great skill in the art of management to bear most effectively in these relations.

The Divisional Advisory Boards

Advisory Boards to each of the divisions and branches in NRCL have either been established, or are in the final stages of formation. Preceding each divisional review in the pages that follow will be found a list of the membership of the division's Advisory Board. A typical Board has perhaps four or five members from industry, four or five from universities, and two or three from other government departments and elsewhere. Many are well-known scientists and engineers capable of understanding and appraising the details of the scientific projects; others, such as company presidents and senior executives have been invited to sit on the Boards because of their broad knowledge of industrial technology and the demands of the marketplace. No NRC staff are members of these Advisory Boards.

While most of the Boards have been formed rather recently, two or three are several years old and, in particular, the Advisory Board to the Division of Building Research can boast of a tradition extending back at least fifteen years.

The primary function of an Advisory Board is to furnish advice to the divisional Director on the one hand, and to Council through the Vice-President (Laboratories) on the other. Among its responsibilities a Board acts as an independent standing review committee. The Board's advice is listened to and never swept under the rug, though for one reason or another it may not be possible to act on all of it, particularly in this current era of severe financial restraint. However, it is a pleasure to be able to record that many of the critical assessments and positive suggestions put forward already by several of the Boards have been most helpful, and some have indeed led to changes both in organization and in emphasis of program.

As the President himself has remarked, if I may again quote his words in his 1969–70 Report, "The hundred or so outside experts sitting on NRCL Advisory Boards are able to subject the laboratories to a much more searching scrutiny than Council members could ever hope to do alone. In a very real sense, then, the members of the Advisory Boards are not only acting *in loco parentis* to Council, but are effectively working extensions and therefore a part of Council". Consideration is now being given to enlarging and strengthening that role by effectively bringing the Boards together, probably through a committee of Board Chairmen to which could be delegated some of Council's duties and powers.

D. W. R. McKINLEY

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Biophysics

Hydration of Biopolymers

The state of water in the hydration shell of DNA was studied by infrared spectroscopy. At low temperatures an inner layer of about 10 H_2O molecules per nucleotide is incapable of crystallization, even when the surrounding water crystallizes into ice. Biopolymer hydration shells are not "ice-like" in the sense of crystalline ordering into an ice-like lattice.

Hydrogen Bonding

Infrared absorption profiles of the OH stretching bands of phenol and 2,6-diisopropyl phenol in solution, liquid, and crystalline phases were studied as a function of temperature. The profiles reflect the distribution of OH . . . solvent interactions.

Infrared Spectra and Structure of Liquid Water

The molar absorptivity of dilute HDO in water and in aqueous NaCl solutions has been determined between 10 and 85°C in the spectral region 2000–4000 cm^{-1}. Differences in the Raman and infrared profiles have been explained. Band profiles of NaCl solutions indicate a wide distribution of ion-H_2O interactions, akin to the distribution of H_2O-H_2O interactions of liquid water.

Isosbestic points (i.e. common points of intersection for spectral band profiles at different temperatures) in the infrared spectrum of water can be explained without postulating the existence of two "species". Isosbestic points are a common occurrence, and have been observed for ice, in which there is certainly no equilibrium between two types of molecules.

Infrared profiles of the OH and OD stretching profiles of HDO in aqueous solutions of dimethyl sulphoxide have been studied. There is no indication either of hydrogen-bond breakage or of any tendency towards clathrate or iceberg formation around dimethyl sulphoxide.

Attempts to verify the existence of "anomalous water", reported by several researchers in Russia and in the U.S.A., have failed. The published evidence for a new form of water has been examined and found unconvincing. The most likely explanation for "anomalous water" is contamination.

Infrared Spectra of Water in Crystalline Hydrates

In order to obtain more information on the role of water in systems of biological interest, we have begun a spectroscopic study of water in simple, thoroughly understood crystalline hydrates. The first two compounds investigated were gypsum ($CaSO_4 \cdot 2H_2O$), and sodium chloride dihydrate. Further investigations are in progress.

Chemical Biology

Attention has focussed mainly on tracing pathways used by microorganisms to biosynthesize economically important metabolic products. In this work fermentation processes for the antibiotics chloramphenicol, caerulomycin, etamycin, mitomycin and terreic acid have been investigated, and new information obtained on the biosynthesis of gibberellins (plant hormones), fusaric acids (plant toxins), and ergot alkaloids (therapeutically useful drugs).

As a necessary adjunct to these studies the structures of metabolic intermediates and novel fermentation products have been determined usually with the collaboration of chemists in this laboratory or elsewhere, and new tracer techniques have been developed. Of the latter, the application of nuclear magnetic resonance techniques to locate and measure the distribution of isotopic labels within a molecule promises to be of far-reaching importance to biochemists, and has been explored with the active collaboration of the Organic Chemistry Section.

The recent rapid advance in knowledge of biosynthetic pathways, metabolic control systems, and genetics, have opened up dramatic new possibilities for directing and manipulating industrial fermentations. To exploit these opportunities the interest of the Chemical Biology Section has shifted. New studies are aimed at establishing the types of metabolic controls which regulate production of antibiotics and other typical secondary metabolites. Evidence of feedback regulation has been found in chloramphenicol biosynthesis, but not in cinnamamide accumulation. In the biosynthesis of ergot alkaloids enzymes are apparently induced by tryptophan, one of the prime precursors, but gene expression is delayed. One explanation of this effect requires the existence of stable messenger RNA and has important implications in developmental biology.

During studies on cinnamamide biosynthesis and its metabolic regulation in *Streptomyces verticillatus* the enzyme L-phenylalanine ammonia-lyase was discovered for the first time in a bacterium. It is similar in most respects to the enzyme found in plants, and other indications that phenylalanine ammonia-lyase may have widespread but sporadic distribution in microorganisms suggest that evolution of higher plants, if based on expanded phenylpropanoid metabolism, did not necessarily depend upon appearance of this key enzyme.

Chemistry of Natural Products

Structures of New Natural Products

The structure of a new weakly basic alkaloid, which was isolated from *Ipomoea alba* L., and given the trivial name Ipalbidine, was shown to be 1,2,3,5,8,9-hexahydro-6-*p*-hydroxyphenyl-7-methylindolizine.

A phytoalexin produced by alfalfa in response to

fungal infection was identified as (-)-dimethylhomopterocarpin.

Proton and Carbon-13 Magnetic Resonance

The location of incorporated ^{13}C-label, in excess over that of natural abundance (1.1%), in the tropolone sepedonin (3,6,9-trihydroxy-3-methyl-1,3,4,7-tetrahydrocyclohepta[c]pyran-7-one) produced in cultures of *Sepedonium chrysospermum* containing formate-^{13}C, acetate-1-^{13}C or acetate-2-^{13}C has been determined by comparing the relative intensities of the ^{13}C-satellites in the PMR spectra. Results indicated that biosynthesis involved a polyketide chain containing ten carbon atoms derived from acetate and a one carbon unit derived from formate. The biosynthetic pathway was unequivocally confirmed by direct observation of the ^{13}C resonances. These experiments constitute a new non-destructive approach to the investigation of biosynthetic problems.

Hydrogens which differed only in their axial or equatorial orientation exhibited different ^{13}C—H spin-spin coupling constants. Studies were initiated to investigate the reasons for such differences.

The conformations of dihydroipalbidine, *O*-acetyl dihydroipalbidine and other substituted indolizidines were investigated at 100 MHz.

Computer programs NMRIT and NMREN were used to carry out complete analysis of the PMR spectra of a large number of carbohydrate derivatives and of four stereoisomeric 1,2-diacetyl-3,4-dicarbomethoxycyclobutanes.

Nuclear Overhauser experiments were used to elucidate the structure of sepedonin.

Synthesis and Reaction Mechanisms

Two of the three possible stereoisomeric di-adducts produced by reaction of furan with dimethyl acetylene dicarboxylate, or ethyl propiolate, have been identified. In both cases the reaction rate and product composition are markedly affected by the presence of $AlCl_3$.

A new synthetic procedure has been developed for synthesis of polysubstituted aromatics. Appropriately substituted dienes (furans or pyrroles) and acetylenic dienophiles reacted in the presence of $AlCl_3$ to form 7-oxa- or 7-azanorbornadienes which readily rearranged to polysubstituted phenol or aniline derivatives. Photochemical conversion of the norbornadienes to 3-oxa- or 3-azaquadricyclanes followed by thermal isomerization gave high yields of oxepines and azepines.

Suitably substituted 3-oxaquadricyclanes have been converted quantitatively to substituted cyclobutanes. This constitutes a new approach to the synthesis of cyclobutanes and the scope of the reaction is at present being investigated.

Irradiation in the UV converted 7-oxanorbornadienes to 3-oxaquadricyclanes, oxepines and 6-hydroxyfulvenes, the product of reaction being dependent on the substituents and experimental conditions. In the presence of iodine, however, irradiation gave 6-hydroxyfulvenes exclusively. The mechanism of this new synthesis is at present under investigation.

Studies on the effect of Lewis acids on the Diels-Alder additions of heterocyclic dienes with acetylenic dienophiles have continued. Spectroscopic (IR, UV, PMR and ^{13}CMR) investigations on the Lewis acid complexes which may be involved in the reactions have been carried out with a view to elucidating the mechanism of reaction and the role of the Lewis acids.

Final experiments on the kinetics of the acid and base catalyzed alcoholysis of trialkylalkoxysilanes were carried out. The results of this detailed study will lead to new approaches in the synthesis of derivatives of polyhydroxy compounds.

Studies to determine the basic factors controlling the reactivity of secondary hydroxyl groups in methyl glycosides, and to evaluate the relative thermodynamic stabilities of derivatives of the methyl glycosides have been continued.

High Temperature Chemistry

Polymer Theory

Theoretical expressions were derived for the most probable distribution of molecular sizes in branched polymers. The results, which differ from previous expressions in the literature, yield insight into the configurational aspects of branching processes and lead to modified views concerning the phenomenon of gelation in polymeric systems generally.

The above theory was used to interpret the thermodynamic properties of binary silicate melts. The predicted variation of activity with composition agreed with experiment for all systems so far studied. The results provide a firm theoretical basis for understanding the properties of glasses and metallurgical slags.

Constitution of Silicate Melts and Glasses

The method of acid treatment and simultaneous trimethylsilylation was applied to the study of the constitution of silicate glasses. The trimethylsilyl derivatives were separated by gas-liquid chromatography and analyzed by high resolution mass spectrometry. Complications due to side reactions were minimized and a direct method of trimethylsilylation was developed and tested with minerals of known structure.

In line with theoretical conclusions, discrete silicate anions of various chain lengths were found in lead silicate glasses. The change in anionic constitution caused by the transition from the glassy to the crystalline state was studied and compared with measurements of X-ray diffraction.

A study of the anionic constituents of lunar glass was initiated, with samples of lunar fines from Apollo 12.

Work was continued on the thermodynamics of cobalt silicate melts by equilibrating the melts at 1450–1600°C with atmospheres of known oxygen potential. An unexpected finding was the predominance of linear chains in this system, as inferred from the data, and further work is in progress to verify this conclusion.

Slag-Metal Equilibria

A new technique was developed for the study of slag-metal equilibria. Specimens of slag and metal were levitated by electromagnetic induction and samples of each phase removed at equilibrium for analysis. The technique was used to measure the solubility of oxygen in liquid iron and the activity of FeO in ferrous silicate slags at temperatures up to 1960° C. The method permits study of systems which have hitherto been difficult or impossible to investigate due to the lack of suitable containers.

Kinetics

The rate of removal of sulphur by hydrogen from molten Fe-S alloys is decreased by dissolved oxygen. This is due to competition for H_2 between sulphur and oxygen, and the results were interpreted in terms of the equilibrium constants of the competing reactions. The rate of vapourization of levitated drops of iron is enhanced by oxygen in the gas phase, and the competition for oxygen between the drop itself, and the vapour, has been studied. The oxidation of Fe-C-S melts by argon-oxygen mixtures is being investigated. Oxygen-free Fe-C-S alloys are made by mixing carbon and sulphur powder with sponge iron, pressing the mixture into pellets and sintering them at 900°C.

Instrumentation

The instrumentation laboratory has been concerned largely with the development and modification of instruments in the fields of nuclear magnetic resonance and mass spectroscopy. Improved scanning capabilities have been added to the 100 MHz Varian HA-100 NMR spectrometer. Development of the high resolution Bell and Howell/CEC 21–110B mass spectrometer includes: a wide-range, temperature-controlled probe for the direct introduction of samples; most of the construction and assembly of a modification allowing electrical field ionization of samples; a circuit to correct for non-linearity in magnetic scanning; a safety control and alarm circuit to protect the instrument against failures in the vacuum, cooling and power systems.

Some selected electrical reference standards and instruments have been acquired for instrument calibration purposes. A program covering the maintenance of scientific instrumentation has been developed. Cooperation has continued with other groups in adapting instrumentation to their research requirements.

Lichenology

The biosynthetic pathways of *Pseudocyphellaria* are being studied for a better understanding of the physiology, chemistry and chemotaxonomy of lichens. Numerous aromatic compounds have been isolated and identified from various species: 1. The orsellinic acid esters methyl orsellinate, methyl lecanorate, methyl evernate, methyl gyrophorate, 4-*O*-methyl gyrophoric acid and tenuiorin, as well as the β-orsellinic acid depsidones stictic, norstictic and constictic acids, all representing polyketide derived compounds. 2. The pulvinic acid derivatives calycin, pulvinic dilactone, pulvinic acid, and pulvinamide which originate from the shikimic acid pathway.

It is considered likely that the nitrogen in pulvinamide is derived from the amino group of phenylalanine whose carbon skeleton is incorporated as a whole into pulvinic acid derivatives. A newly proposed pathway of pulvinic acid biosynthesis employs pyridoxal-bound intermediates making polyporic acid a by-product rather than an intermediate as in the earlier proposals. A (protein-) bound form of pulvinic acid must also be postulated from experiments with pulvinic-^{14}C acids which rapidly become bound up in the acetone-insoluble fraction of the lichen before being converted into calycin.

Aldehyde-positive and negative strains of *Pseudocyphellaria anthraspis* have been found growing at random under identical ecological conditions. This must mean that either a genetically variable fungus or alga participates in the species of lichens concerned. Chemical work on lichen compounds from other genera has been completed (dendroidin, papulosin) or is underway.

Studies on the taxonomy and distribution of peat mosses have been carried forth with the help of a graduate student from Laval University (R. Gauthier) but will be discontinued as a major project. Activity in this field at present is restricted to some collaboration on the checklist of Canadian bryophytes.

Marine Botany I
(Biochemistry and Physiology)

Studies on the low-molecular weight carbohydrate derivatives of the algal flagellate *Monochrysis lutheri* showed that cyclohexane tetrol behaved as an osmotic regulator when the organism was subjected to changes

in salinity. A new natural product, 1,3,5/2,4-cyclohexane pentol was also discovered in, and isolated from this plant.

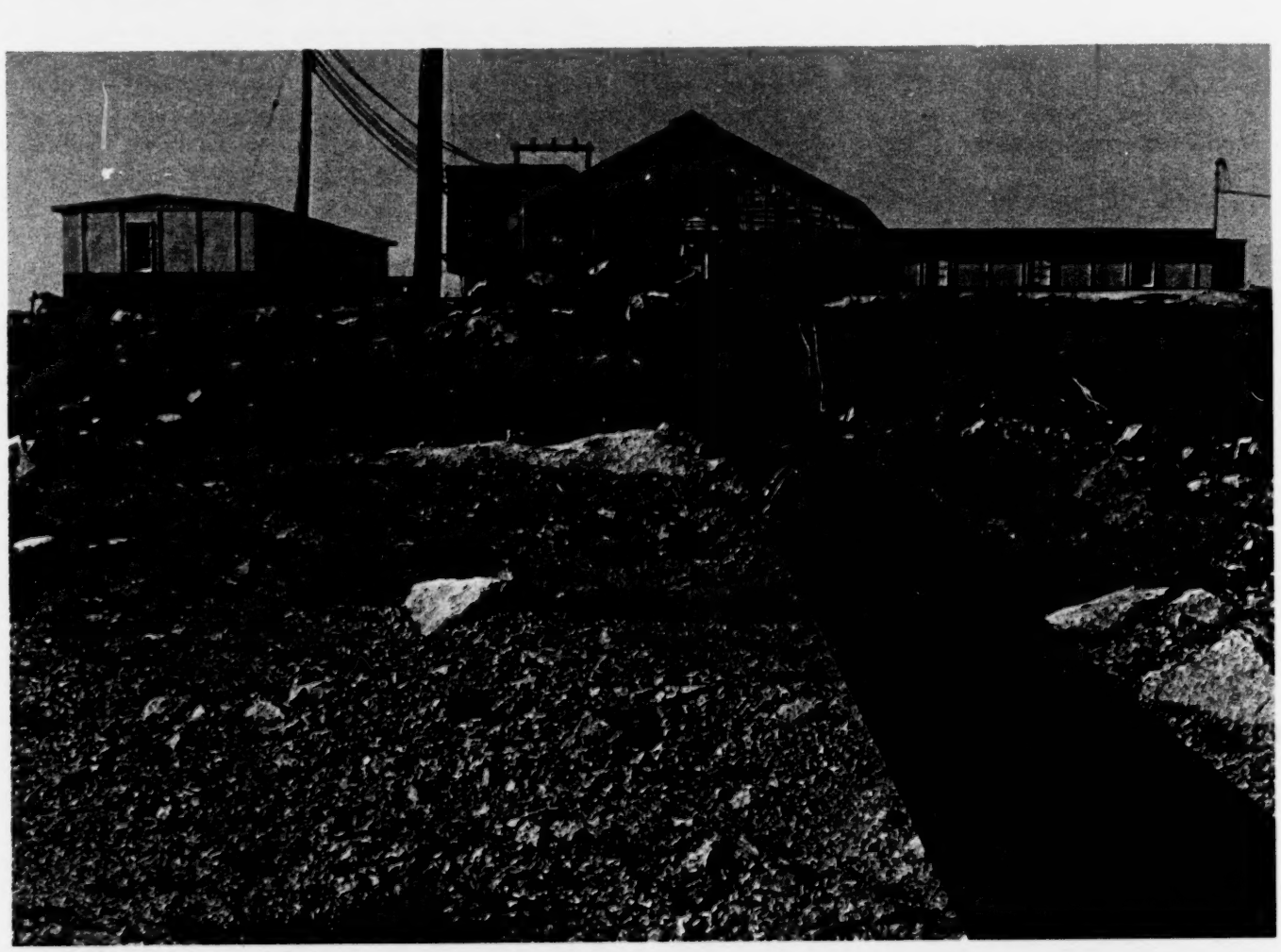
Investigations of proteins extracted from algae have centered on the isolation, purification and characterization of algal cytochromes. A simple and reliable procedure of protein extraction was developed and is now in routine use.

Some factors affecting the growth and development of *Laminaria* gametophytes are under examination. Analyses of cultured, filamentous gametophytes revealed that their principal components are alginate, fucoidan, laminaran and mannitol.

Marine Botany II
(Systematics and Ecology)

The seaweed survey of Nova Scotia has continued, and additional species new to the province and new to North America have been recorded. Observations of the algal flora of the Digby Neck area were made on a year-round basis; of the 187 species and varieties recorded, 76 are new records for the Bay of Fundy and 11 are new records for North America. A detailed study of several species including *Petroderma maculiforme, Ralfsia fungiformis* and *Melanosiphon intestinalis* has been completed. The algal herbarium at the Atlantic Regional Laboratory now contains approximately 7500 specimens. The majority are from Nova Scotia, but also included are collections from the west coast of North America, Japan, the British Isles and the Mediterranean.

The life history of species of Phaeophyceae and Rhodophyceae has been investigated in culture. The crustose plant previously recognized as *Ralfsia clavata* is an alternate phase in the life history of *Petalonia.* Temperature apparently controls release of conchospores in both *Porphyra miniata* and *P. linearis.* Large, mature thalli, which formed spores, were obtained in culture. Tetraspores of *Bonnemaisonia hamifera* gave rise to male gametophytes only. Male plants were also found along the Atlantic coast of the province during winter; this is the only record for male gametophytes in North America.



The seaweed research station at Fink Cove. Seawater is pumped through the large pipe.

Marine Laboratory

The marine laboratory is situated at Fink Cove (Sandy Cove), Halifax County, N. S. about 16 miles from the Atlantic Regional Laboratory. This is a group of small buildings situated on a 65-acre seaside site. It comprises, at present, a glasshouse (1800 sq. ft.), a culture house (1300 sq. ft.), a laboratory-office building (1700 sq. ft.) and several smaller structures including a pump house and a workshop. This site is undergoing gradual development. A continuous stream of running seawater has been supplied to the glasshouse since July 1969. It has been used primarily for studies on the cultivation of Irish Moss (*Chondrus crispus*), which is the seaweed of greatest economic importance in this region. A preliminary report on this work is given in the NRC publication SCIENCE DIMENSION, Vol. 2, No. 1 under the title "Crops from the Sea". The vegetative propagation of Irish Moss continues to be the main field of investigation. The long range objectives are selection of improved strains and development of economically-feasible methods for their propagation.

Mass Spectrometry

In collaboration with others, mass spectrometry has been applied to study reactions and structures of ions formed by electron-impact fragmentation of brominated vanillyl alcohols, other halogenated aromatic compounds, sporidesmins, perfluorophenyl sulphides, trimethylsilyl ethers of silicates extracted from glasses, hydroxyindole-3-carboxylic acids, hydroxyskatoles, depsides and acetyl derivatives of methyl xylosides.

Development of microanalytical methods using mass spectrometry centered on indoles as well as halogenated aromatic compounds of the type used as pesticides. Conclusive information was obtained using low resolution mass spectrometry with microgram amounts of sample which had been isolated by thin-layer chromatography. High resolution mass spectrometry with photographic plate detection was used to determine residues of the fungicide 2,6-dichloro-4-nitroaniline at levels down to 0.01 ppm in microgram samples of a crude plant extract.

A wide-range, controlled-temperature, direct-introduction sample probe which was developed has been used extensively. Sample temperatures are known and controllable from −150°C to 200°C, are independent of ion source temperature and can be changed rapidly enabling study of highly volatile or thermally unstable materials. A double-focussing, medium resolution mass spectrometer which is suited for coupling to gas chromatography columns has been installed.

A service was established whereby scientists not at the Atlantic Regional Laboratory are provided high resolution and other mass spectral data on mailed samples. The data requested often depend on experimental techniques not readily available elsewhere. Scientists thus aided included staff from universities, other laboratories of the National Research Council of Canada and laboratories of other government agencies.

Microbiology

The activity of this section has been directed mainly at an investigation of the possible microbiological factors involved in poor growth of ruminants in northern Nova Scotia. It has been found that the growth of micro-fungi in soils of this region is greatly stimulated towards the end of July each year, and that this growth continues until the middle of September. At the same time the number of bacteria in the rumen of animals grazing the pasture decreases significantly, thus accounting for their poor growth.

A very large number of isolates of fungi have been made during this work and of these about 50 are isolates of *Chaetomium* sp. About 10% of these *Chaetomium* isolates are efficient producers of chetomin in laboratory culture. This antibiotic(s) is of unknown structure, and indeed purity, but sufficient is known of its chemistry and biology to enable its inclusion in the group of toxic fungal metabolites of which sporidesmin is an example. Sporidesmin is probably involved in the aetiology of diseases of ruminants in Australia, New Zealand, and the United States. We have isolated many metabolites related to sporidesmin and determined their chemical structures. These metabolites include the first tri- and tetrasulphides ever to be isolated from natural sources.

Chetomin inhibits the growth of rumen bacteria and has an LD_{50} in sheep of 5 mg/kg. We have also shown in collaboration with colleagues at the University of Minnesota, that it is involved in diseases of hogs fed fattening corn infested with *Chaetomium globosum*. Our investigations of its chemistry have revealed new aspects of the organic chemistry of sulphur, particularly with respect to the stereochemistry of polysulphides and the stereoisomeric course of their reactions with nucleophiles.

Under different conditions of laboratory cultivation *Chaetomium* sp. produce another antibiotic which appears to be unrelated to chetomin. It also is of unknown chemical structure and has the interesting property of inhibiting the respiration, and therefore the growth of several plant pathogenic *Fusarium* sp. Perhaps, more interestingly, it also inhibits the growth of *Pseudomonas* sp. isolated from the fabric of the local general hospital.

Physiological Chemistry

Studies are continuing on the influence of such factors as: (1) the structure of the aminochrome; (2) the structure of the thiol, and (3) the reaction parameter in general on the course of the reactions that occur between aminochromes and thiols. In general three types of product are formed: (A) 5,6-dihydroxyindoles; (B) 4-thiolsubstituted 5,6-dihydroxyindoles, and (C) addition products derived from the thiol and the aminochrome. Preliminary spectroscopic studies have shown that at pH = 2-4 formation of type A and type B products is favoured, whilst at pH = 5-7, the formation of type C products predominates.

The reactions of epinochrome with reducing agents have been studied. True leuco-derivatives of epinochrome can be isolated, if suitable precautions are taken to prevent their re-oxidation. The important aminochrome, noradrenochrome, and a number of its derivatives have been obtained for the first time as crystalline solids.

The products obtained by the action of strong acids on catecholamines have been investigated. The correct structure for the product, obtained by the action of 20% HCl on adrenaline, and which was previously described as diadrenaline ether has been shown to be 6-(3′,4′-dihydroxy-α-methylaminomethylbenzyl) adrenaline. The trivial name adrepine was suggested for the base. Improved procedures for the bicycloheptadiene derivative of adrenaline, known as adnamine, have been developed.

A number of potentially physiologically active β,β-diphenylethylamine derivatives have been prepared by the action of hydrochloric acid on mixtures of a β-phenylethanolamine derivative, such as adrenaline, with a second phenolic component, which may be either a simple phenol or a second hydroxyphenylethanolamine component.

The significance of reactions of this type in the explanation of the formation of some substances responsible for the formation of artifact spots in catecholamine chromatography has been considered. In solvents containing *n*-butanol and HCl, adrenaline *n*-butyl ether is formed and in solvents containing phenol and HCl β-(*p*-hydroxyphenyl)-β-(3′,4′-dihydroxyphenyl) ethylmethylamine is formed. Both of these products have been synthesized by unambiguous routes.

Extensive n.m.r. and mass spectroscopic studies have been made of the trimethylsilyl and acetyl derivatives of adrenaline and a number of related compounds.

A new alkaloid ipalbidine and its β-D-glucoside ipalbine have been isolated from the seeds of *Ipomoea alba* L. The structure of the weakly basic alkaloid ipalbine ($C_{15}H_{19}NO$) has been shown to be 1,2,3,5,8,9-hexahydro-6-*p*-hydroxyphenyl-4-methyl-indolizine. A degradation product, 5-*p*-hydroxyphenyl-4-methyl-2-*n*-propyl-pyridine was obtained on selenium dehydrogenation of ipalbidine. Dihydroipalbidine was formed on catalytic hydrogenation of ipalbine. The p.m.r. spectra and mass spectroscopic fragmentation patterns of ipalbidine, dihydroipalbidine and their *O*-acetyl derivatives support the structure proposed for ipalbidine.

The 4,5,6 and 7-hydroxyindole-3-carboxylic acids were synthesized by an unambiguous route. Some of these isomers were previously reported from chromatograms of mammalian urine but assignment was impossible because of lack of standards. Procedures for the separation of all four isomers by thin layer and liquid partition chromatography were worked out. Hydroxylation of indole-3-carboxylic acid with Fenton-Cier reagent gave all four hydroxy isomers.

Methods were developed for the isolation, separation and identification of indole auxins and related naturally occurring indoles. Successful procedures involve ion exchange and partition chromatography, nondestructive detection sprays, derivative formation, phosphorescence spectroscopy and mass spectrometry. These methods are now being applied to complex indole mixtures from natural samples.

The chemistry of pesticides and new analytical methods for pesticides, their metabolites and related pollutants is being investigated. Phosphorimetry of aromatic fungicides, residue analysis by mass spectrometry and use of electron donor and acceptor complexing sprays for TLC detection and direct mass spectrometric identification are recent research projects.

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BIOCHEMISTRY LABORATORY

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The Biochemistry Laboratory was formed in November 1968, from a group of scientists who have had a common interest in the study of biological processes at the molecular level. These scientists were formerly in the Divisions of Biosciences, Pure Chemistry and Pure Physics, and consist of biochemists, organic chemists, physical chemists and physicists. The Biochemistry Laboratory thus takes advantage of the unique ability of the National Research Council Laboratories to form interdisciplinary groups when desirable and necessary.

To encourage the interdisciplinary approach the Laboratory is not organized formally into sections. Instead, there are a few main lines of research as indicated in the body of this report. Individuals work within one or more of these lines as collaborations develop on the basis of common interests. The objective is to make significant contributions to the understanding of biological processes and the unifying theme is the relationship between structure and biological activity or function.

During the past year significant advances have been made in several lines of research. These include (a) the production and isolation of proteolytic enzymes from bacteria and determination of their amino-acid sequences, specificities and reaction mechanisms, (b) the isolation and characterization of polysaccharide antigens from yeasts, fungi, and bacteria, (c) application of nuclear magnetic resonance, electron spin resonance and optical rotatory dispersion to study conformations of nucleic acids and model membrane systems. Details of these and of other work are given below.

Enzymology and Protein Chemistry

Dr. D. R. Whitaker and *Dr. H. Kaplan* have concentrated their efforts on two projects: (1) the proteolytic enzymes of *Sorangium sp.*, a myxobacterium from Ottawa soils and (2) the properties of particular side-chains of enzymes and other proteins. Work on the bacterial enzymes has been concerned with the production and isolation of individual proteases and with the determination of their amino acid sequences, specificities, and reaction mechanisms. Tests on industrial applications have been made in collaboration with the research laboratories of Canada Packers Ltd. The second project is, in part, a continuation of a project from Dr. Kaplan's postdoctoral research at the Institute of Molecular Biology in Cambridge, utilizing the technique of competitive labelling developed by him and Dr. B. Hartley.

The main developments during the past year were as follows. (a) The complete amino-acid sequence of the α-lytic protease of *Sorangium* was determined in collaboration with Dr. L. B. Smillie of the University

of Alberta. (b) The properties of this enzyme have been compared in detail with those of pancreatic elastase, an enzyme which it matches both in enzymatic properties and in the sequences around the amino acids with essential catalytic functions. A reaction mechanism applicable to all serine proteases has been formulated. (c) A determination of the sequence and reaction mechanism of the β-lytic protease of *Sorangium sp.* is in progress. Although it is an endo-peptidase, not an exopeptidase, there are strong suggestions that this enzyme will prove to have a relationship with carboxypeptidase, another protease of the mammalian pancreas. (d) the δ- and ϵ-proteases of *Sorangium sp.* are serine proteases with an unusual sequence of amino acids at their reactive serine residues. The former has a trypsin-like specificity; the latter has a "reversed chymotrypsin"-like specificity: it cleaves linkages involving aromatic amino acids but the point of cleavage is at the imino group, not at the carboxyl group. (e) The pK's and the reactivities of the amino groups of porcine elastase have been determined by competitive labelling. Similar studies on trypsin and chymotrypsin are in progress. A method which may enable the same technique to be applied to histidine residues is under investigation.

Dr. H. Schneider has been studying membranes with the following objectives. (a) Elucidation of the mechanism of active transport of sodium and potassium across membranes. (b) Isolation and characterization of the components involved in this process. (c) Elucidation of the structural and functional roles of lipids in membranes. (d) Determination of the mechanism of action of drugs on membranes and of antibiotics which affect transport processes.

To investigate the mechanism of active transport a hydrogen-tritium exchange technique and the spin-label method were used as molecular probes. These methods revealed conformational changes in membrane proteins during the action of the enzyme adenosine triphosphatase in human erythrocyte membranes. This enzyme is associated with transport phenomena in membranes. The spin-label method revealed a magnesium-dependent conformational change in the membrane protein, a fact of some interest since the enzyme requires magnesium.

The spin-label method was also used to evaluate extraction procedures for isolating membrane proteins without denaturation. A number of fractions have been obtained where dissolution produced only minimal structural changes.

A new technique has been developed for studying the role of lipids in membranes. It consists of the formation of oriented phospholipid films in which spin-labelled lipids have been intercalated. The angular dependence of the electron spin resonance spectra of these films provides information about the ordering and motional freedom of the spin label and hence about the phospholipids. It has been shown that cholesterol markedly influences the ordering and motional freedom in egg lecithin films and that it can also control the location of membrane components. Ordering effects were also found to be caused by anesthetics and antibiotics. All of the e.s.r. and spin-labelling studies were done in collaboration with *Dr. I. C. P. Smith.*

Dr. W. G. Martin has been investigating the isolation and structural characterization of soluble and insoluble lipoproteins. He has collaborated with Dr. Schneider and Dr. Smith in the isolation of membrane lipoproteins, a representative of the insoluble class.

Serum lipoproteins are representative of the soluble class and have been implicated in atherosclerosis and other cardiovascular disorders. These lipoproteins can be classified by their densities and can be resolved by solvent extraction, zonal centrifugation and gel filtration. Examination of porcine serum lipoproteins showed that the lipids in the various fractions did not differ in their content of phosphorus or cholesterol and that their amino acid compositions were similar. The range of molecular weights in these materials is due to accretion or loss of lipid.

Some aspects of the lipoprotein disorder, Hyperlipoproteinemia, were studied in collaboration with Dr. J. C. Nixon (Ottawa General Hospital). From 14 members of a family, 3 were found to have different manifestations of the disorder and their lipoprotein characteristics were determined.

The effect of estrogens on rat serum lipoproteins was investigated in collaboration with Dr. P. Hill (Wallace Laboratories). The estrogens altered the lipid content and changed the rate of turnover of lipoproteins, resulting in a three-fold increase in the amount of very low density lipoprotein.

A study of the conformations of serum lipoproteins by spin-labelling and e.s.r. has been started in collaboration with Dr. Smith.

Immunochemistry

Dr. G. A. Adams has been studying the endotoxins of Gram-negative bacteria. Chemically, these are lipopolysaccharides in which both the lipid and polysaccharide moieties contribute to the toxic and antigenic properties.

During the past year the lipopolysaccharides of several species of *Neisseria* were studied to see if there were similar patterns in their chemical compositions. The lipopolysaccharide of *N. perflava* contained D-glucose, L-rhamnose, L-glycero-D-manno-heptose, 2-keto-3-deoxyoctulosonic acid, D-glucosamine and D-galactosamine. The same components occurred in *N. sicca* with the exception of L-rhamnose. *N. catarrhalis*, *Moraxella duplex* and *Micrococcus calco-aceticus* contained D-glucose and D-galactose but lacked heptose and 2-keto-3-deoxyoctulosonic acid. The lipid portions of all the lipopolysaccharides were similar to each other in structure and composition. It was estab-

lished for the first time that the D-glucosamine units in lipid A are joined by glycosidic bonds, not by phosphodiester bonds as was thought previously, and the location of these linkages was determined. The main fatty acid component for all of the lipids was β-hydroxymyristic acid which was attached to D-glucosamine through an amide linkage.

Dr. C. T. Bishop has been working on the polysaccharide antigens of pathogenic yeasts and fungi. In yeasts, the serological determinant is thought to be a mannan that is present on the outer layer of the cell wall. The mannans from several species of *Candida* were isolated and their structures were compared. The results showed that all of the mannans were very similar, if not identical. Serological tests showed strong and extensive cross reactions. It was concluded that the mannans are common antigens in this group of organisms.

Similar results were obtained with a series of 15 dermatophytic fungi. Each organism contained the same pattern of three polysaccharides in the cell wall: two galactomannans and a glucan. Only minor differences in structure were found in the polysaccharides from different organisms. Extensive cross reactions were obtained in serological tests and it was concluded that these polysaccharides were common antigens for the whole group of dermatophytic fungi.

A new method has been developed for preparing synthetic antigens. It consists of linking a carbohydrate, acting as a hapten, to an antigenic carrier protein, utilizing a controlled step-wise reaction with cyanuric chloride. Such a conjugate formed with a galactomannan and bovine gamma globulin induced highly specific antibodies to the galactomannan in rabbits.

Dr. H. J. Jennings has isolated a capsular and an exocellular polysaccharide from the yeast *Tremella mesenterica*. The exocellular polysaccharide was found to be a glucan containing α, $1 \rightarrow 4$ and $1 \rightarrow 6$ linkages. The capsular polysaccharide was a glucuronoxylomannan; its structure has been established and correlated with its serological cross reactions.

Antisera prepared in rabbits against the cell-wall of *penicillium patulum* contain antibody directed to the cell-wall $1 \rightarrow 3$, α-linked glucan. However, this antibody was shown to be non-specific. An antisera has been prepared to the whole cell to compare the specificity of the antibody produced in this way.

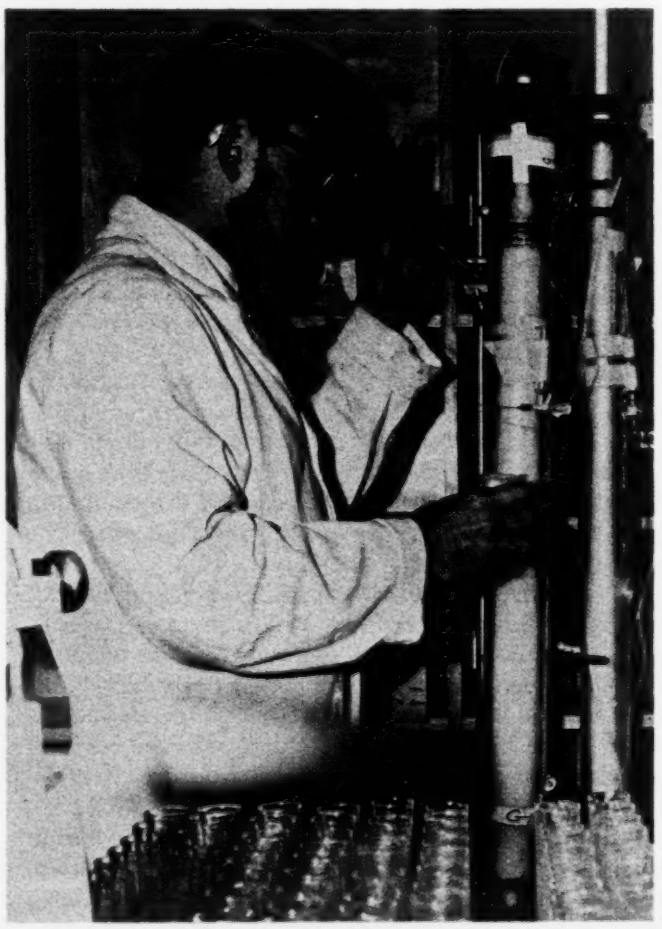
Dr. M. B. Perry has been on educational leave for one year from July 1969. He has been working on the structure of immunoglobulins in the Medical Research Council Laboratory at Cambridge, England.

Synthesis of Biologically-Active Compounds

Dr. O. E. Edwards has been studying the structure and synthesis of physiologically active compounds—antibiotics, steroids, alkaloids, anti-cancer agents. The synthesis of a new series of steroids has been achieved and new synthetic methods for the preparation of amines have been developed. The structure of a toxin from fresh-water algae has been determined. Several new cucurbitacins (anti-tumor compounds) have been isolated and characterized. The biosynthesis of the alkaloid dendrobine was shown to involve successive cyclization and fission of a sesquiterpene precursor.

Dr. S. F. MacDonald's work on pyrroles and porphyrins concerns the biosynthesis of the latter and the development of reductive C-alkylation as a synthetic and analytical method.

The α-free-α-aminomethyl-tripyrrane postulated as an intermediate in the biosynthesis has been synthesized in the form of the ethyl ester of its lactam. Many pyrroles are now more easily obtained by reductive C-alkylation, usually with an aldehyde and hydriodic acid. This procedure greatly simplifies the analysis of porphyrins. It has also been found that meso-substituents in porphyrins can be identified and located



First step in the gene synthesis purification of synthetic fragments by using the sephadex gel filtration technique, which has been perfected in the Biochemistry Laboratory. This photograph shows the application of a chemical reaction mixture on a sephadex column, through an automatic sample applicator.

through the pyrroles. The Hantzsch pyrrole synthesis, heretofore of very limited value, was extended to give 2-alkyl- and 2,4-dialkylpyrrole-3-carboxylic esters.

Dr. S. A. Narang has as his main objective the synthesis of a gene containing the information for the A chain of insulin. New and efficient methods have been developed for the synthesis of deoxyribopolynucleotides containing 5′-phosphomonoester end group. A new method has been established for incorporating radioactive phosphate at the 5′-hydroxyl of an oligonucleotide. The use of polynucleotide ligase is being exploited as a synthetic tool to join chemically synthesized deoxyribooligonucleotides. It has been shown that polynucleotide ligase does not recognize one mispaired base in the joining reaction. Methods are being developed for the synthesis of the anticodon loop of a transfer RNA. The availability of this loop will open a way to study the function of t-RNA at a more precise molecular level.

Dr. R. E. Williams is working on the synthesis of peptides and nucleic acid bases to be used in the investigation of the processes involved in both normal and abnormal cell development. These include peptides expected to have activity in controlling the *in vitro* translation (DNA-DNA; DNA-RNA) and transcription (RNA-protein) processes known to be involved in the cellular conversion of the information in DNA into protein. Other peptides are being prepared as aids in the study of an enzyme thought to be involved in the initial stages of protein synthesis and responsible for the cleavage of the methionine amino acid initiator from the N-terminal portion of the growing protein chain.

The synthesis of some alkylated adenines has been started. These compounds, having cytokinin-like activity, are related to a rare base found in several t-RNAs. It is expected that they will allow the investigation of the active site of a recently isolated t-RNA alkylating enzyme.

Physical Methods

A good deal of the work in application of physical methods to biological systems has involved X-ray crystallography both of small organic systems and of biological macromolecules and development of the appropriate methodology.

Dr. F. R. Ahmed and *Dr. A. W. Hanson* have studied the following systems during the past year: triphosphonitrilic and diphosphatriazine compounds with varying ligands to determine the effect of the ligands electronegativity on the stereo-chemistry of these six-membered rings of complex orbital systems; charge-transfer and ionic complexes; overcrowded *cis* and *trans* [2.2] metacyclophanes and their steric properties; 3-bromoacetoxy dienonitrile to determine its conformation and relation to the Moscowitz rule for steroids; 5- and 6-membered organometallic chelate rings (boron and antimony) to relate their structures and spectral properties.

Dr. Hanson spent some 9 months in the Molecular Biophysics Department of Yale University acquiring the special skills of protein crystallography. He is now collaborating with *Dr. Whitaker* in attempts to grow suitable crystals of the β-lytic protease of *Sorangium sp.*, and with *Dr. Przybylska* to grow crystals of the haptoglobin-hemoglobin complex.

Dr. G. I. Birnbaum, Dr. C. P. Huber and *Dr. M. Przybylska* have collaborated on a number of projects. It has been found, by X-ray analysis, that the structure of the diterpenoid alkaloid, lappaconine, is closely related to that of delcosine and lycoctonine. However, lappaconine has some novel structural features that precluded the determination of structure by chemical means.

Programs have been developed for the solution of non-centrosymmetric crystal structures by direct methods and these have been added to the N.R.C. set of crystallographic computer programs. The structures of *p*-nitrophenyloxazine and of the alkaloid denudatine have been determined using these programs. Denudatine is a diterpenoid alkaloid with a new type of skeleton which was postulated (by K. Wiesner and E. Valenta) as a possible intermediate in the biogenetic transformation of the atisine skeleton into the aconitine type. The structure of a lactam intermediate encountered in alkaloid synthesis was determined by the symbolic-addition procedure to be different than originally predicted. The structure of the alkaloid delnudine was expected to be a simple derivative of hetisine, but the X-ray analysis of its hydrochloride showed it to contain a novel ring system. Data were collected for sporidesmin G etherate. The main interest in this microbial toxin lies in the fact that it has four sulfur atoms forming a bridge across a piperazine ring. The X-ray analyses of a tetracyclic diketone, of importance in K. Wiesner's new method for the synthesis of bridged terpenoids, and of a lupine alkaloid, α-isosparteine diperchlorate, have reached the final stage of least-squares refinement. The structure determination of a bis-iron-tricarbonyl complex of a propellane is in progress.

Several grams of pure haptoglobin, type 1-1, have been obtained from ascitic fluids from carcinoma patients. A complex with horse hemoglobin was prepared and numerous crystallization trials yielded hexagonal crystals. Their suitability for the X-ray structural determination has not yet been established.

Dr. I. C. P. Smith has been applying the techniques of nuclear magnetic resonance, electron spin resonance, optical rotatory dispersion and optical absorption to studies of biological systems at the molecular level.

Complete three-dimensional models have been obtained for the structures of β-pseudouridine, uridine, and their various phosphate derivatives (2′, 3′, 5′,

cyclic) by detailed analysis of their high resolution n.m.r. spectra. A study was made of the relative binding efficiencies of normal and rare nucleosides to clarify the role of the latter in tRNA. The molecular conformations of the degenerate codons UpUpU and UpUpC were compared using n.m.r. at 220 MHz; it was concluded that they were identical. A detailed study of $tRNA^{Ala}$ revealed that the rare bases, particularly dihydrouridine, were tied up in a region with a high degree of organization, and were not as mobile as an open cloverleaf model would suggest. N.M.R. is also being applied to study the binding of hormone-protein complexes using storage proteins (neurophysins) and hormones (oxytocin, vasopressin) from porcine pituitaries.

Spin-labelled derivatives of RNase A have been made, isolated, and characterized. The e.s.r. spectra of these derivatives were used to gain information about various regions of the molecular structure. The influence of substrate or inhibitor binding, pH, temperature, on these regions was investigated.

Further spin-labelling, e.s.r. studies included the cross reactivity and time-dependent specificity of rabbit antibodies and the nature of the combining site in the hemoglobin-haptoglobin complex. The conformation change involved in the formation of the latter complex resembled that which occurs in the oxygenation-deoxygenation equilibrium. Collaborative work with *Dr. Schneider* and *Dr. Martin* on conformational changes in membranes and lipoproteins was described under *Enzymology and Protein Chemistry*.

Cell Biochemistry

The work in cell biochemistry has involved studies of the structure and function of key components in specific cell organelles. The systems under investigation are the mitochondrium and its role in the energetics of the cell, the ribosome and its role in protein synthesis, the nucleus and its role in genetic expression, and the structure and biosynthesis of cell walls.

Dr. C. V. Lusena has been trying to relate changes in mitochondrial development and function to changes in mitochondrial structural protein. A suitable collection of yeast mutants has been established and methods have been developed to limit exponential growth, for isolation of yeast mitochondria, and for resolving mitochondrial structural protein. It has been shown that the mitochondrial structural protein from mutant yeasts lacks two major components that are present in the same material from wild strains. Similar differences in structural protein have been found in the cell membranes of mutants.

Dr. A. T. Matheson has isolated the ribosomal-bound aminopeptidase found in *Escherichia coli* B. The enzyme has a molecular weight of 60,000 and is made up of subunits. Sulfhydryl groups and Mn^{2+} are required for full activity. The enzyme shows a strong preference for leucyl and methionyl peptides while alanyl, seryl, valyl, and glycyl peptides are poor substrates. A comparison of substrate specificity with the known N-terminal sequences of *E. coli* proteins suggest that this enzyme may be involved, in conjunction with peptide deformylase, in the removal of the N-formyl-methionine initiation group from newly synthesized polypeptide chains. The peptidase is found both in the ribosomal and soluble fractions of *E. coli* and it appears that its location can change during the growth cycle, a property common to other factors involved in protein synthesis. Work on *Sorangium* ribosomes and polysomes and their components, RNA and protein, has been handicapped by the presence of nucleases and protease even in ribosomes that have been washed. The properties of the protease and the effect of growth conditions on its activity have been studied.

The nature of the recognition by certain ribosomal proteins of specific regions in the ribosomal RNA is under investigation using the 30S ribosomes of *E. coli* Q-13 and the thermophilic bacteria *B. stearothermophilus*. Methods are being developed to isolate and purify the specific ribosomal proteins and ribosomal RNA.

Dr. J. M. Neelin has been studying the relations among chromosomal macromolecules, the control of nucleic acid transcription, and cellular differentiation in avian erythrocytes, a highly specialized cell line with simplified functions. Systems for analysis, fractionation, and characterization of histones, a major group of chromosomal proteins, have been developed particularly to permit the study of an unusual, highly basic histone characteristic of these cells. These methods are being adapted to the micro-quantities of protein available from purified, immature erythroid cells. The erythrocyte-specific histone appears to be present along with the five universal types of histone as early as middle erythroblast stages, even though the chromatin is not yet fully condensed, and nucleic acids and hemoglobin are still being synthesized. However, removal of the cell-specific histone from the fully repressed, condensed nucleus of mature cells by selective acid extraction causes changes in the ultrastructure of the chromatin and markedly increases the availability of DNA for priming of RNA synthesis.

Chromosomes also contain a significant amount of nonhistone protein which is synthesized more rapidly than histones, especially in absence of cell division, and which responds readily to environmental stimuli, including appropriate hormones. These proteins have been difficult to extract and analyse, but a novel method of solubilization in phenol with salts and detergent has revealed an array of proteins of various molecular weights. Such proteins, extracted from chicken erythrocyte nucleoprotein residues after his-

tone removal, are resolved well by gel electrophoresis. Changes in the constitution and metabolism of these proteins will be studied in relation to cell development and the capacity of the chromatin to support nucleic acid synthesis.

Dr. J. R. Colvin has been investigating microfibril formation in cells. The transient, immediate precursor of cellulose has been isolated and purified by a combination of chromatographic methods. It has been partially characterized as a lipid glucoside and the structure of the aglycone is being determined.

A lipid has been isolated from cultures of *A. xylinum* which has the capacity to influence the direction of deposition of cellulose microfibrils. This compound was shown to be a steroid with a cholestane skeleton, to which is attached an aliphatic chain with hydroxyl groups on each of the four outermost carbon atoms. The mechanism of orientation of the cellulose microfibrils by this compound is now being studied.

Determination of the structure of the tunics of ascidians provided additional evidence that the general mechanism of cellulose microfibril formation is the same in animals, bacteria, and plants.

A new method was developed for determining the distribution of cystine-containing proteins within the cell walls of plants. Some or all of these proteins are enzymes responsible for synthesis of the cell wall components and this new method should permit their location in the cell to be established much more precisely by electron microscopy.

A preliminary study of the mechanism by which a plant protoplast may regenerate a new cell wall was completed. This study led to an investigation of the exterior surfaces of suspension-cultured plant cells (in cooperation with *Drs. D. Rose* and *S. M. Martin*, Div. of Biology) and to the discovery of a new microfibrillar component of plant cells.

Dr. B. F. Johnson has been studying the growth or control of growth of the cell wall and mitochondria of yeasts. The sites of extension of the glucan layer in the walls of three radically different yeasts have been demonstrated by quantitative autoradiography. 2-Deoxyglucose has been found to induce lysis exclusively at those sites of glucan synthesis. Other relevant results are (a) the induced lysis occurs only if cells are growing, (b) the rate of initiation of that lysis is strictly proportional to the rate of cellular extension, (c) the molar ratios of 2-deoxyglucose to glucose are less important than the growth dependency, (d) 2-deoxyglucose induces dissolution of previously synthesized glucan, (e) recovery from the early stages of lysis is very rapid after removal of 2-deoxyglucose. Based on these facts a mechanism has been proposed for growth of the glucan layer by controlled cutting of glucan molecules by a hypothetical endoglucanase followed by insertion of glucose into the breaks. Evidence for the presence of an endoglucanase has been obtained and its properties are being investigated.

Yeast cells survive and grow well even in the complete absence of mitochondrial respiratory function. It is therefore possible to study a wide range of nuclear gene-induced mitochondrial defects. Progress to date indicates that the mitochondrial genome may not be the target for ultraviolet light induced non-segregational loss of mitochondrial function.

Publications of the Biochemistry Laboratory, 1968–70

Enzymology and Protein Chemistry

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The Division of Biology was formed in the fall of 1968 by joining about two thirds of the staff of the former Division of Biosciences to the staff of the former Division of Radiation Biology. At this time, critical examination of the research activities of the integrated groups resulted in termination of some programs and establishment of new ones. The present research activities are carried out by eight groups of scientists in the three main areas of Environmental, Food and Radiation Biology. In addition, the Biomathematics group studies problems of interest to cell biologists and provides assistance on statistical problems to the whole Division.

At the beginning of 1969, the Radiobiology group of DRB's Defence Research Establishment in Ottawa was closely integrated with the NRC Radiation Biology groups.

Experimental animal facilities available to all Ottawa laboratories of NRC have been centralized in the Division.

A brief account of the work carried out in the current programs, along with some results obtained in programs terminated during the period covered by this report, is given in the following sections.

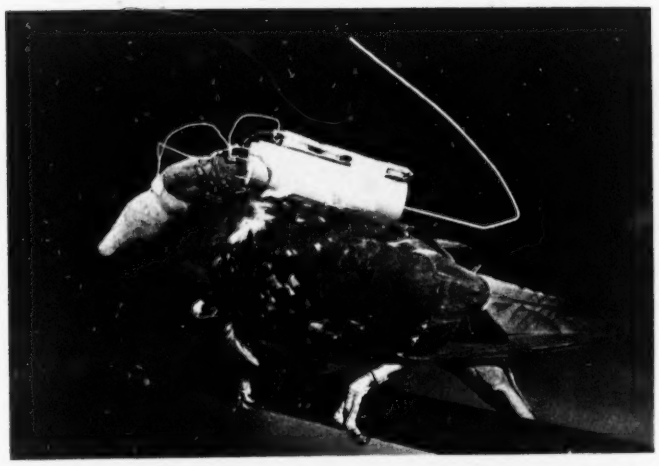
ENVIRONMENTAL BIOLOGY

Environmental Physiology

Physiological Studies on Bird Flight

Collaboration between the Divisions of Radio and Electrical Engineering and of Biology in using the technique of radio-telemetry, has provided the first direct measurements of body temperature regulation during flight and of coordination between breathing and wing movements in birds. The studies, now terminated, also included development of new techniques for measuring pulmonary ventilation and oxygen consumption during flight.

The results indicate that the heat production in flight varies between 12–17 times the basal rate, and that the body temperature and heat loss are probably both independent of air temperature through the regulation of convective and evaporative losses. Unknown regulatory mechanisms function to greatly facilitate



Pigeon fitted with transmitter designed by REED for the study of bird flight by the Environmental Physiology group in the Division of Biology. These studies provided new data on the relationship between respiration, heart beat and wing beat during flight in many species of birds.

heat transfer through the feathers to levels greatly in excess of that expected from tests with an inanimate model system. Respiratory water loss estimated by measurements of pulmonary ventilation and nasal temperature accounts for less than 20% of the total heat loss, but this loss nevertheless exceeds metabolic water production except at very low air temperatures (black ducks).

Breathing in all birds except the pigeon is regulated independently of wing movements, but there is usually a coordination of phase relationships and frequency ratios. The latter varies within and between species from 1:1 coordination ($\frac{\text{wing rate}}{\text{resp. rate}}$) in pigeons and crows to 5:1 coordination in quails and pheasants. Determinations of heart rates and oxygen consumption generally gave higher estimates of cardiac output capabilities for birds in flight than for mammals of comparable weight and work load.

Bioenergetics and Activity of Peromyscus

Also, in collaboration with R.E.E.D., a study has been completed on the energy metabolism in Peromyscus leucopus, estimated from both food intake and oxygen consumption; on body temperature from radio-telemetry; and on activity of mice in nest boxes and in enclosures outdoors. The objective was to determine the magnitude of seasonal changes in energy utilization and associated changes in temperature regulation and activity resulting from the seasonal changes in our climate.

Seasonal changes in energy metabolism were relatively small and the yearly average was approximately 10 K cal/day or about twice the basal level. The metabolism was somewhat lower during the winter than at other seasons, in keeping with grouping of the mice and with periodic torpidity. In single nontorpid mice prevented from huddling, the metabolism was higher than at other seasons in conformity with the lower winter temperatures. Thus, behavioural and physiological adjustments in this species completely compensate for the tendency of cold weather to increase energy metabolism. Torpidity in single mice may result in a fall in body temperature from 37° to 20°C, and a fall in metabolism to 1/4 the basal level. Similar changes occurred at any time of the year as a result of fasting.

Access of mice to an outdoor enclosed area did not elevate metabolism above that for mice confined to nest boxes. Activity resulted in a peak in oxygen consumption around midnight during summer and usually two peaks during winter. These animals preferred to be active on the snow surface during winter, even though the only food supplies were available in nest boxes under the snow.

Bioenergetics and Catecholamines

Catecholamines, and more particularly noradrenaline, have been linked with development and control of nonshivering thermogenesis in the cold-acclimated rat. The mechanism of control of heat production by the catecholamines is still unknown but has been related to uncoupling of phosphorylations from oxidations. This would be supported by the observation that the increase in heat production elicited by a single injection of dinitrophenol is strictly additive to that elicited by a continuous infusion of noradrenaline when both treatments are combined. In another study, the three compounds dinitrophenol, adrenaline, and noradrenaline, were shown to elicit different effects on oxygen consumption level and on plasma glucose and lactic acid concentrations, but this pattern of change with time was similar in warm- and in cold-acclimated rats. Current studies examine involvement of tyrosine, both as a precursor for catecholamine synthesis and as an indicator of possible amino acid participation, as substrate for the thermoregulatory response.

Diet and Cold Resistance

When rats are fed a commercial rat food preparation, cold-acclimation is usually accompanied by an increased thyroid activity. However, recent work has revealed that with a thyroxine-free semi-synthetic diet, supplemented by iodine in the drinking water, rats become acclimated to cold without the usual signs of a greater thyroid involvement, such as heavier thyroid, higher resting metabolic rate, faster thyroxine turnover rate and greater fecal excretion of thyroxine. Further work has then shown that in spite of this apparent normal thyroid activity, rats fed this semi-synthetic diet had a much greater degree of cold resistance than rats fed the chow diet.

On the basis of the numerous similarities between the physiological and pathophysiological reactions to chronic cold exposure, thyroxine administration and dietary deficiency of magnesium, the hypothesis was evolved that magnesium requirement may be increased in the cold and that a semi-synthetic diet was

more apt than a commercial chow diet to supply the required amount of this ion.

A study of Mg^{++} metabolism as related to diet and environmental temperature has now been initiated.

Water and Salt Balance in Marine Mammals

In a collaborative study with Prof. H. D. Fisher at the University of British Columbia, measurements of water and chloride fluxes in seals starved or fed herring of known water and chloride content showed that seals could survive extended periods of starvation without excessive dehydration and that water needs could be satisfied by the food eaten. Sea water drinking was estimated by an indirect method and found to amount to about 10 ml per 100 g of fish ingested. This observation indicates that sea water intake in the seal is probably a consequence of eating under water and is not due to deliberate drinking. These data provide answers to old-standing questions in the biology of marine mammals.

Environmental Pollution

The Environmental Pollution group was formed in 1969 by staff drawn from the Animal Physiology, Plant Physiology and Microbiology sections of the former Division of Biosciences. The current primary objective of this group is the investigation of the kinetics of transfer, degradation, toxicity and detoxification of biocides, principally chlorinated hydrocarbon insecticides, in animals, plants and microorganisms. The studies will provide quantitative information on the risk to environmental stability arising out of the use of such toxic and persistent chemicals.

DDT Biokinetics in Small Mammals and Birds

DDT and other fat-soluble pollutants accumulate in individual organisms and become concentrated in so-called food webs by transfer from prey to predator. This process results in the development of hazardous levels of pollutants in the fatty tissues of individuals occupying apical positions in food webs. In recent studies, the extent of retention of ingested DDT has been found to vary greatly from one species to another. Pigeons retained all the DDT ingested; ring-billed gulls and white rats retained respectively 40% and 10% of the amounts fed. Chronic exposure of rats to low temperatures (6°C) resulted in still lower retention. The rate of DDT clearance from pigeons increased from 0.1% to 0.3% of body burden per day after depletion of some 50% of lipid reserves during starvation. The amount of DDT transferred from adipose tissue to skeletal muscle was at least 30 times greater than the amount of DDT excreted in feces and urine during the same period of time. The accumulation of DDT in skeletal muscle suggests the possibility of a DDT effect on the peripheral as well as the central nervous system. On recovery from starvation, DDT in muscle was relocated into adipose tissue. These results will permit prediction of hazardous DDT levels which may be reached in birds under conditions of increased energy expenditure such as cold exposure and migration.

DDT and Plants

Plants may accumulate pesticides as a result of intentional surface application, unintended fallout at locations remote from spraying operations, and possibly by absorption through the roots. The knowledge and experience gained in earlier studies of assimilation and translocation processes in plants are being used to evaluate the extent and means of pesticide absorption. The earlier studies included work on the quantitative movement of sugar in and out of leaves. Mature leaves achieved the maximum transfer rate (3–5 mg $C/dm^2/hr$) about two hours after the beginning of the photosynthetic period. During the dark period, export from these leaves decreased to a low value. Immature leaves imported carbon to supplement photosynthetic assimilation but also actively exported carbon during the night. Sites which control the movement of sugars within and out of leaves have been studied by radioautography and cyanide inhibition techniques. These sites are now thought to be physically located within groups of cells near the ends of blade veinlets. Preliminary studies on root uptake of DDT by beets in hydroponic culture indicated preferential accumulation in immature leaves. Technical problems were encountered which were attributed to the deposition of externally-derived airborn DDT on the experimental material. Although this DDT was readily and totally extracted by cool, non-polar solvents, it was retained on leaf surfaces in unchanged form and quantity for at least four months in spite of exposure to wind, rain and sun.

DDT and Microorganisms

Microorganisms play an important role in the maintenance of environmental stability; they mediate the breakdown of organic detritus, facilitate the biological recycling of materials and affect both the stability of biocides and their environmental circulation. In the laboratory they provide convenient model systems for study of biocide uptake and for study of effects at the cellular level. Changes in the numbers and kinds of bacteria in natural populations provide a sensitive indication of environmental changes. Some of the work carried out in the former Microbiology Section was directed towards the detection and characterisation of such changes in bacterial populations in agricultural soils. Collaborative work on the use of numerical techniques for describing bacterial populations is now being terminated. To obtain background information, the ability of DDT to inhibit

growth of 180 strains drawn from 18 common genera of heterotrophic bacteria has been tested. No Gram-negative organisms were affected but representatives of 4 Gram-positive genera were inhibited. Preliminary observations suggest that the conditions under which tests are conducted (e.g. nature of DDT solvent employed) greatly influence the results obtained.

The NRC Culture Collection is being maintained: this facility is in effect a "library" of living microorganisms and provides services to NRC, to Government and University laboratories and to Industry. Current holdings include 746 strains of bacteria, 256 fungi, 114 yeasts, and 7 bacteriophages. In 1968, 146 cultures were provided in response to requests and in 1969, 385 cultures were distributed. Specific problems relating to the preservation of these microorganisms are investigated.

FOOD BIOLOGY

Cell Culture

Plant Cell Culture

Inasmuch as complete plants may be derived from single cells growing in isolation, it follows that any product of a plant is a potential product of cells derived from that plant. Among the products identified in plant cell cultures are: alkaloids, antibiotics, carbohydrates, cardiac-glycosides, enzymes, growth regulators, lipids, proteins and steroids. This potential for the biosynthesis of economically important plant constituents led, in 1969, to the formation of a multidisciplinary group to study cultivation of isolated cells of higher plants. The techniques of cell culture, the physiology and biochemistry of cultured cells and the chemistry and metabolism of products of potential commercial importance, including protein, are being studied. In addition to the work on plant cell culture, members of the group are continuing some bacteriological studies and are providing microbiological services on an interdivisional basis.

Studies on the techniques of plant cell culture have progressed favourably. Production of actively-growing, relatively homogeneous cultures has been assured by use of a specially designed "V"-fermenter and special culture techniques. The use of such cultures as inocula has led to more uniform experimental results. To provide the large amounts of cell material necessary for chemical and biochemical studies, *Ipomoea sp.* and *P. vulgaris* cells have been cultured in commercially available fermenters. No serious difficulty has been experienced in scaling up from "V"-fermenters, through 7.5 and 14 liter-fermenters, to a 150-liter stainless steel fermenter. Growth rates of 1.3 g dry tissue per liter per day (mass doubling time, 52 hours) have been attained.

The comparative nitrogen requirements of three cell lines *(Phaseolus vulgaris, Ipomoea sp.* and *Daucus carota)* grown in suspension culture in a medium containing enzymatic casein hydrolysate, KNO_3 and $(NH_4)_2SO_4$, has been studied.

Cell suspension cultures of *P. vulgaris* excrete large amounts of peroxidase into the medium. The effect of nutrients on production of cell mass and of enzymes has been examined. For production of both cells and enzyme a preference for energy source was shown, the order being glucose-sucrose-fructose-maltose. Lactose, starch and some organic acids were utilized to a slight extent. Of the complex nitrogen sources tested, enzymatic casein hydrolysate was utilized most readily but not all commercial preparations were equivalent. Kinetin and 2, 4-D, but not indoleacetic acid and naphthaleneacetic acid, were required for growth. The concentration of hormones optimum for growth was also optimum for enzyme production. Of the vitamins tested, only nicotinic acid and inositol were required for growth and enzyme production.

Two peroxidases were isolated from culture filtrates of *P. vulgaris*. Enzyme I was purified 145-fold and had an Rz value of 3.08 (Rz of crystalline horseradish peroxidase = 3.04), while enzyme II was purified 725-fold and had an Rz of 1.94. The molecular weights, as determined by gel-filtration, were 30,000 and 6,000 respectively. The two enzymes showed different electrophoretic mobilities but were quite similar in respect to pH optimum, heat stability, substrate specificity and the effect of inhibitors.

Cell suspension cultures were also shown to produce high levels of intracellular acid and alkaline phosphatases. Alkaline phosphatase, but not acid phosphatase, were repressed markedly by inorganic phosphate in the medium.

Biochemical studies to date have necessarily been focussed on the development of methods suited to analysis of these cultures. Cell wall material comprises 15 to 18% of the dry cells, and contains 4 to 10% protein (N $\times$ 6.25). Total protein (N $\times$ 6.25) varies from 15 to 45% of the dry cell, depending on growth conditions and other factors. Lipid content varies from 4 to 8%, of which about half is neutral lipid material. Three Dragendorf positive compounds (alkaloids) have been detected in extracts of *P. vulgaris* cells, and two of these have been isolated by T.L.C. Extracts and media of five cultures have shown antibiotic activity against selected test organisms.

Attempts to determine DNA and RNA in cultured cells have been unsatisfactory to date, but are being continued. Methods of estimating the total number of cells and the number of viable cells are being investigated.

A culture collection comprising plant cell lines derived from 19 plant species is maintained within the group. The following families are represented in the collection: Apocynaceae (3), Chenopodiaceae

(1), Compositae (1), Convulvulaceae (2), Seguminoseae (2), Moracea (3), Solanaceae (6), Umbellifereae (1).

Microbial Cell Culture

Cultivation of lactic streptococci in chemostats for production of dairy starter cultures has been studied. *Streptococcus cremoris* and *S. lactis* have been grown in broth media and in modified milk in an all-glass laboratory chemostat. Data have been gathered on the effect of pH, temperature, and dilution rate on the production of viable cells. In addition, viability of cells during storage at 4°C and −40°C has been examined. The results suggest that the continuous culture technique will produce starter cultures of high activity.

During the above studies, a filamentous variant of *S. cremoris* was isolated. The cells of this culture appear to have defective cell wall and/or septum forming processes. They are being examined for possible use in studies of the chain-forming process in streptococci.

The effects of growth conditions on the lipopolysaccharide composition of *Neisseria sicca* have been studied in cooperation with Dr. G. A. Adams (Biochemistry Laboratory). When *N. sicca* cells were grown in shake flasks the lipopolysaccharide contained glucosamine and galactosamine in the ratio of 1:0.6. This ratio changed to 1:8 in cells grown in stirred-jar fermenters at high aeration rates (i.e., high growth rates) and to 1:1.6 at low aeration rates (low growth rates). Also, the lipopolysaccharides from cells grown rapidly contained a greater percentage of unsaturated fatty acid (oleic) than did that from cells grown slowly. This suggests that the process of unsaturated fatty acid synthesis in this bacterium is similar to that described in yeast. These results indicate that the influence of environmental conditions on cell wall composition must be considered when cells are grown for studies of antigenic materials and for vaccine production.

Studies on the effects of dicarboxylic acids on proteinase production by *Micrococcus sp.* (ATCC No. 407) led to the observation that carbon dioxide stimulated growth of the organism. Cells grown in the presence of carbon dioxide contained an increased amount of malic enzyme. It was shown that cell-free extracts fixed carbon dioxide in the presence of pyruvate, NADPH and Mg^{++} and that the product of the reaction was malate. Although malic enzyme, which catalyzes the reductive decarboxylation of malate, was one of the first enzymes shown to fix carbon dioxide in animal tissue, its activity in this reaction had not previously been shown in bacteria. (The latter project was terminated during the period under review.)

The problem of the bacteriological degradation of keratinaceous materials was investigated. Of the 50 strains of myxobacteria (mainly cytophages) tested most were able to solubilize autoclaved feathers but none attacked unmodified feathers. The strain studied most extensively rapidly solubilized up to 80% of the substrate leaving only the resistant shafts. In the absence of a readily assimilable energy source, such as glucose, about 70% of the protein nitrogen solubilized appeared as ammonia which the organism could not use. Glucose exhibited an amino acid sparing effect. Production and properties of the extracellular proteolytic enzyme produced by this strain *(Cytophaga johansonii)* was the subject of further studies. The partially purified enzyme preparation contained two main protein components but only one was proteolytic. The pH optimum (7.5–9.0 with different substrates) indicated that it was an alkaline protease. Gel filtration indicated that the molecular weight of the enzyme was about 65,000. The enzyme was dependent on Ca^{++} for stability and, in the alkaline pH range, soluble proteins also acted as stabilizing agents. Inhibitors, such as iodoacetic acid, p-chloromercuribenzoate, N-ethyl-maleimide and natural trypsin inhibitors did not inhibit the enzyme but metal-complexing did, suggesting that the enzyme is a metallo-protein. The enzyme occurs naturally as a tightly bound protein/polysaccharide complex which appears to play a considerable role in the overall "economy" of the organism in its natural environment. (This project was terminated during the period under review.)

The group has continued to provide extensive microbiological services on an interdivisional basis. These services have consisted of providing large quantities of microbial cells for biochemical studies, providing laboratory-scale fermenters for individual workers, providing sterilizing and incubating facilities and offering assistance and advice on matters relating to the cultivation of microorganisms.

Milk Proteins

Published reports have indicated that the para-*K*-casein isolated from casein after treatment with the milk-coagulating enzyme, rennin, was heterogeneous. By chromatography on carboxymethyl cellulose, one major and two minor components were isolated from para-*K*-casein, but analysis and other means showed that the minor components were artifacts induced by the carbamylation of lysine while the protein was dispersed in urea solution. Further study showed that the para-*K*-casein is identical regardless of the genetic variant of *K*-casein used for its preparation, and contains 108 amino acid residues (mol. wt. about 13000).

Kappa-casein macropeptides released from *K*-casein components by the action of rennin are highly heterogeneous. *K*-Casein macropeptides from *K*-casein A were fractionated into at least nine fractions by DEAE cellulose column chromatography. The major component was carbohydrate-free, and other fractions contained variable amounts of carbohydrates (N-acetylagalactosamine, galactose, sialic acid). The carbohydrate-free macropeptide from *K*-casein A consisted of 58 amino acid residues, and had the following composition: Asp 5, Thr 11, Ser 6, Glu 9,

Pro 7, Gly 1, Ala 4, Val 5, Met 1, Ile 5, Leu 1, Lys 3. The molecular weight of this component was estimated to be about 6170. The carbohydrate-containing peptides from *K*-casein A had the same amino acid composition as the carbohydrate-free major component. The macropeptides from *K*-casein B had the same total number of amino acid residues, but it had one more residue of Ala and Ile, and one less residue of Asp and Thr.

Work on milk proteins is now being terminated.

In addition to performing the above studies, members of the group have collaborated extensively with staff of the Biochemistry Laboratory on structure of cell-wall lipopolysaccharides and on the determination of amino-deoxy-sugars.

Food Technology

During the past two years most of the effort of this group has been devoted to four projects: poultry processing and handling, vegetable storage, beef processing and handling, and food plant waste treatment. The first two of these have been major studies for the past 15 years but are now being phased out. The effort is being transferred to the second two projects, both started during the past year. Work on a fifth project, fundamental aspects of the freezing and storage of biological materials, is being continued.

Poultry Processing and Handling

Studies on biochemical and tenderness changes occurring during post-mortem aging of poultry indicate that pre- and post-mortem glycolysis greatly influence the rate of post-mortem tenderization as well as ultimate tenderness. Extensive glycolysis occurring immediately before and during slaughter lowered the post-mortem pH and caused rapid onset of rigor mortis. The rapid onset of rigor mortis and the lower pH reduced the rate of tenderization and ultimate tenderness.

Studies on the growth of spoilage microorganisms on poultry during refrigerated storage have shown that growth and off-odor occur first on the skin. Differences in growth rates on various tissues were due to differences in lag period. Studies on bacteria-induced biochemical changes in the skin showed that pigmented pseudomonads are more proteolytic than other groups of psychrotolerant spoilage organisms and are collagenolytic. Study of methods for assessing bacteriological quality have shown that the ERV (extract release volume) test can be used to assess the bacterial count of the skin because the water holding capacity of the skin tissue decreases linearly with bacterial growth. The test is not reliable for other tissues.

Vegetable Storage

The object of most of the vegetable storage work has been to increase the storage life of Canadian grown vegetables and reduce loss of quality during storage. The work has included studies of storage physiology and the development of the jacketed type of refrigerated storage room. The results have shown that storage life of apples, carrots, cabbage, celery, parsnips, potatoes and rutabagas can be increased by up to 50% by increasing relative humidity from the usual 85–95% to 98–100%. Fundamental work to explain the reduced incidence of decay at the higher relative humidity (contrary to common knowledge) showed that decay-causing microorganisms produce less enzyme capable of dissolving pectin at the higher humidity.

Physical studies included measurement of heat of respiration and coefficients of moisture loss for varieties of vegetables commonly grown and stored in Canada, as well as measurement of temperature gradients and rates of air movement under various storage conditions. In addition to jacketed apple storages constructed earlier, the work has resulted in the construction of the first jacketed vegetable storage. Measurements and discussions with the owner during the first year enabled him to make important improvements.

Beef Processing and Handling

Work on beef processing and handling has been undertaken in cooperation with a major packing company. Four aspects of the problem are under study: tenderness, microbiology, weep, and freezing—all related to central pre-packaging, a major goal.

Study of the factors influencing tenderness, including "between animals" variability, requires sampling a large number of animals of similar breed and rearing conditions and various pre- and post-slaughter treatments. Since this degree of control is difficult to obtain with large animals, as much of the work as possible is being done with poultry, and the results applied to beef in more limited tests. Tests made with the Longissimus dorsi and Psoas major muscles of beef indicate that the effects on tenderness of pre- and post-mortem glycolysis in beef are similar to the effects in poultry meat.

Initial study of the effect of the gaseous environment on the growth rate of psychrotolerant spoilage microorganisms shows that 20% carbon dioxide in transport and storage atmospheres increases shelf life markedly, depending on temperature and incubation time, without harmful side-effects. The use of these results in conjunction with plastic film packaging is being studied. The minimum oxygen requirements for spoilage microorganisms is also being determined.

Initial measurements showed that weep varied by a factor of four with kind of muscle, and by a further factor of two with pressure (as when packages are stacked on top of each other). Aging time, direction cut with respect to direction of fibers, and treatment

of the surfaces with salt solutions had no effect. Exposure to ammonia vapor (20 sec) prevented weep altogether. Further studies will include the effects of coatings and the surface properties of packaging materials.

In a first series of tests on freezing, the effects on appearance of packaging, freezing rate, storage time, temperature and light exposure were studied. The most natural appearance was produced by air blast freezing at 0 to −20°F. Rate of change of appearance during storage depended on oxygen permeability of the packaging film, temperature (particularly above 0°F), storage time, and exposure to light. Samples exposed to light at 20°F changed appreciably within 1–3 days. After 4 months there were marked changes in the flavor of samples stored under unfavorable conditions.

Food Plant Waste Disposal

This project was undertaken because of the difficulty many food processing plants, particularly those in rural areas or small centers, have in disposing of waste. In many instances the waste is highly concentrated, nutritionally unbalanced, and variable in nature or produced intermittently. The lagoons and irrigation systems now widely used leave much to be desired in many locations. Anaerobic digestion was the treatment method selected for study because it shows promise of being economical and able to handle high strength wastes, although it is used very little for food plant waste treatment. Pear waste was selected as the medium for initial work at the suggestion of a major canning company who felt it was one of the more troublesome wastes, and they are supplying it. Four 30-liter continuous fermenters have been designed, built, and put into operation.

Fundamental Freezing Studies

The study of the modes of action of freezing in damaging biological systems was continued. Previous work with model salt solutions showed that changes in pH and salt composition occurred during freezing as a result of temperature decrease, ice formation and salt precipitation. The information obtained made it possible to study the separate role of each of these factors in freezing damage and a detailed study was made using lactic dehydrogenase, a muscle enzyme, and lipoproteins, an important constituent of all biological materials. Results showed that different factors predominated in the freezing damage to these proteins. For lactic dehydrogenase, a decrease in pH and the temperature drop during freezing caused most damage, as shown by reduced enzyme activity, while increased salt concentration also contributed. The increase in enzyme concentration during freezing, on the other hand, had a protective effect. For lipoproteins, the increase in protein concentration during ice formation was a major cause of protein damage, resulting in protein aggregation, while a decrease in pH and temperature were contributing factors. Cryoprotectants such as glycerol and dimethyl sulfoxide protected lactic dehydrogenase little or not at all, during freezing, but reduced freezing damage to lipoproteins significantly, indicating that these cryoprotectants had no protective action, other than that related to their colligative properties.

RADIATION BIOLOGY

Radiation Chemistry

The Radiation Chemistry group in NRC brings together nine staff members from the Divisions of Chemistry, Physics and Biology who share common scientific interests. The following text reports the activities of the four members of this group responsible to the Division of Biology.

Effects of Ionizing Radiations on Enzymes

Investigation of the effects of ionizing radiation on dilute aqueous solutions of chymotrypsin in air has shown that the hydroxyl radical was the significant inactivating species. The residues first attacked were tyrosine and tryptophan, though correlation between loss of those residues and deactivation was not general for all synthetic substrates. The irradiated enzyme also behaved differently toward each of the protein substrates, haemoglobin, bovine plasma albumin and casein. Comparable results were obtained when the enzyme was irradiated in an oxygen-free atmosphere. This work is being extended to enzyme solutions saturated with N_2O and to higher enzyme concentrations.

The effects of γ-radiation on dilute solutions of trypsin have also been studied using a range of synthetic and protein substrates, with results similar to those described for chymotrypsin.

The effects of ionizing radiation on a series of tryptophan-containing dipeptides were examined using product analysis. This work is being extended with pulse-radiolysis studies.

The unit structure of urease has been examined, employing gel-filtration, ion-exchange chromatography and gradient sedimentation techniques. Apparent conformational isozymes, and a sub-unit of $S_{20,w}$ 12S have been isolated.

γ-Radiolysis of Sulfur-Containing Amino Acids and Peptides (DRB)

Studies of the γ-radiolysis of disulfides of radioprotective and non-protective thiols which had been going on at the DRB laboratories are being continued by DRB personnel who were transferred to NRC early in 1969. Cystine, penicillamine disulfide, and cysteine-penicillamine mixed disulfide have been ex-

Building at the Montreal Road establishment of NRC housing mainly the Radiation and Environmental Physiology groups of the new Division of Biology. Extensive animal facilities, including an operating suite and dog care unit for the Division of Radio and Electrical Engineering, are located in the adjacent structure.

amined, and the work has been extended to cysteine-cysteamine mixed disulfide. This series provides a direct comparison of cysteine in combination with a protective thiol (cysteamine) and a non-protective thiol (penicillamine).

A novel chain reaction was discovered in deaerated solutions of cysteine-cysteamine disulfide which leads to unusually high yields of the symmetrical disulfides. It is suppressed by oxygen, and kinetic studies of the effects of oxygen, N_2O, and disulfide concentration suggest that a simple exchange of RS radicals is involved,

$$RS + R'SSR \rightarrow RSSR + R'S$$

and that O_2 suppresses the chain by reacting with RS radicals to form RSO_2 radicals.

Similar studies of the peptide cysteine-glutathione disulfide, which is a model for the disulfide bridge in proteins, are under way, and show results rather similar to those found with the disulfides previously studied.

Reactions of $RSSR^-$ radical anions in some of these systems are being investigated by pulse radiolysis methods.

Photochemistry of Nucleic Acids and Derivatives

Studies of the effect of phosphate buffers on the photochemistry of certain pyrimidines have been extended to include the influence of detailed chemical structure. It has been found that a 4-amino substituent and a non-enolizable substituent in the 2-position are required for the "phosphate" effect, while substitution in the 6-position blocks it. Further evidence has been obtained that the product results from cleavage at the 1–6 bond. Kinetic studies, and synthetic experiments to characterize the products, are continuing.

The flash photolysis of nucleic acid derivatives is under investigation, in collaboration with Dr. R. W. Yip of the Chemistry Division. Triplet excited states of several pyrimidine bases have been identified as transients in these systems, and characterized. Rate constants have been measured for the dimerization and other loss processes of the triplet states of orotic acid and its methyl ester in aqueous solution. Reactions of the triplet excited state of thymine in acetonitrile and in water have been studied, and the dimerization rate was found to be three times faster in the latter solvent. Parallel to the flash photolysis

experiments, conventional low-intensity studies of the photochemistry of orotic acid and its methyl ester have been carried out.

Structure of Photosynthetic Pigments

Structural studies of chlorophyll *c* obtained from *Phaeodactylum tricornutum* have established that it consists of two chlorophyllides, designated c_1 and c_2, with very similar visible absorption spectra but different structures. Both pigments possess two main visible absorption bands at ca. 629 and 582 nm. Treatment with methanolic hydrogen chloride yielded the respective chloroporphyrin e_6-trimethyl esters, whose molecular weights (determined by mass spectrometry) were 634 and 632. The nmr spectra showed the presence of the C_7 acrylate group. Since both c_1 and c_2 yielded pyrroporphyrin XV, the structure of c_2 requires C_2 and C_4 vinyl groups and that of c_1 a vinyl group at either C_2 or C_4. Extinction coefficients of the phyllins and of the Mg-free derivatives in various solvents were determined, and equations for the measurement of chlorophyllide *c* concentration in the presence of chlorophylls *a* and *b* were calculated.

Some details of the structure of bacteriochlorophyll *b* have also been established.

Radiation Dosimetry

Studies on the metabolism of radionuclides provide information useful in estimating the amount of radiation received by the body and its parts, as a result of accidental internal contamination.

Tellurous acid, labelled with ^{127m}Te, was administered to rats by injection or gavage and the contents of the whole body, tissues, and excreta were measured at various times thereafter by gamma-ray counting. The whole body retention of tellurium as a function of time could be described accurately by a sum of two exponential terms.

Similar metabolic studies were carried out with cobaltous chloride, labelled with either ^{58}Co or ^{60}Co, in mice, rats, rabbits, and men (the last in cooperation with the Radiation Protection Division of the Department of National Health and Welfare). Two types of equation, one a sum of exponential terms and the other a power function, were fitted to the data for whole body retention of cobalt. Statistical analyses showed that a sum of five exponential terms gave the best fit. The retention patterns in mice, rats, and rabbits were almost identical, but the fraction of a dose of cobalt retained for long times after injection was about 10 times greater in man than in the laboratory animals.

At the request of Committee 4 of the International Commission on Radiological Protection, two reports on the evaluation of radiation doses resulting from internal contamination of personnel have been prepared. The first of these, ICRP Publication 10 (1968) deals with single isolated uptakes of radionuclides and the second, ICRP/70/C4-2/5, deals with recurrent or prolonged uptakes.

Radiation Physiology

The Control of Proliferation of Mammalian Cells and the Therapy of Radiation Sickness

Earlier work by this group had established that ionising radiation killed the very radiosensitive lymphocytes (both rat and human) by initiating a phosphate-dependent, respiration-linked reaction which by one hour after irradiation caused the complete and lethal disruption of the cellular deoxyribonucleoprotein structures. More recent model experiments with isolated lymphocyte nuclei established that an identical disruption of deoxyribonucleoprotein complexes and nuclear structure could be produced by exposing the isolated nuclei to phosphoproteins. This led to the hypothesis that radiation induces, or exaggerates, a reaction which causes the phosphorylation of some nuclear protein which, in turn, causes the rapid breakdown of deoxyribonucleoproteins and the death of the cell. This hypothesis has recently been given support by the observation that ionising radiation causes a rapid and large stimulation of the phosphorylation of the histone components of deoxyribonucleoproteins in rat liver cells.

Such studies clearly suggested that a lowering of the phosphate concentration in the cellular environment, or a temporary inhibition of cellular respiration after irradiation could stop the lethal development of radiation damage. These possibilities were confirmed by experiments on rat thymic lymphocytes maintained outside the animal. It has now been shown that post-irradiation administration to rats or mice of either imidazole (which lowers blood phosphate content) or cobaltous chloride (which causes tissue anoxia) considerably increases their survival. Thus, were found some practical approaches to the treatment of radiation sickness.

While it is obviously necessary to reduce cell death in the irradiated animal, it is equally vital to have the technical capability of increasing cell proliferation in order to expedite the repopulation of damaged tissues. During the search for such a capability a large family of compounds was found which can strongly stimulate the proliferation of lymphocytes and bone marrow cells thus uncovering what appears to be a general mechanism of control of cell proliferation in the body. This discovery will be of importance not only to radiation biology, but also to the understanding of both normal and neoplastic (cancer) growth.

Briefly, the proliferation of cells in the thymus

gland and/or bone marrow is affected in exactly the same way by a variety of hormones (neurohormones, parathyroid hormone, prolactin, somatotrophic hormone) and protein kinases (bradykinin). These agents all affect cell proliferation by a calcium-dependent reaction which results in the stimulation of the formation of cyclic adenosine 3′,5′-monophosphate (*cyclic AMP*) by an enzyme embedded in the cell membrane. The cyclic AMP so formed then stimulates the cells to commence the synthesis of deoxyribonucleic acid (DNA). Thus, if one of these hormones (e.g. parathyroid hormone) should be present in abnormally low concentrations, the cells in the thymus gland will lower their cyclic AMP production, chromosome replication will slow down, cell division will be reduced and the gland will eventually atrophy. Alternatively, if this hormone be present in high concentrations, cellular cyclic AMP production and cell proliferation will rise to their maximum values and the gland will enlarge. Finally, the most recent observations suggest the possibility that another hormone, thyrocalcitonin (produced in the thyroid gland) may be used in the body to oppose and thereby regulate the effectiveness of the stimulatory hormones, and would do so by directly interfering with the action of cyclic AMP.

Radiation Protection (DRB)

A continuing search is being made for chemical compounds which can be tolerated by humans and provide protection against ionizing radiation. Based on previous studies of the relations between chemical structure and biological activity, a new series of compounds S-(3-alkylamino-2-hydroxypropyl)phosphorothioates and S-(3-alkylamino-2-hydroxypropyl)thiosulphuric acids are being synthesized and evaluated. The number of carbon atoms in the carbon chain of the alkyl group is being varied from one to ten. It was thought that by increasing the length of the alkyl group, protection could be achieved at desirable dose levels of 50 mg/kg. The dodecyl derivatives of both series were protective in mice. In the case of the thiosulphuric acids, the $LD_{50/30}$ was raised from 778 rads to 1103 rads by a dose level of 15 mg/kg. The phosphorothioate raised the $LD_{50/30}$ to 993 rads at a dose level of 70 mg/kg. The heptyl and octyl derivatives in both series were also protective. Substitution of alkyl groups increases toxicity but protection can be obtained at lower dose levels. The ratios of the LD50 to the therapeutic dose of these compounds are approximately three.

Although a good degree of protection has been achieved at desirable dose levels, further investigations are required to increase the level of protection and determine the pharmacological properties of these compounds.

BIOMATHEMATICS

At the service level, routines were developed for computer digitization of analogue records as required for processing and numerical analysis of experiments in animal physiology and in radiochemistry. Numerical integrations were made of a series of functions specifying radiation dosimetry of internal emitters, and some related dosage-mortality data were graduated.

A two-stage algorithm for non-linear weighted least squares graduation of whole body measurements in radiation dosimetry by sums of exponential functions of time has been developed and applied. In this application, measurements and their errors may range over four orders of magnitude and the latter, unknown *a priori*, must be estimated from residuals.

One method of determining the fraction of a population of mitotic cells in G_1 and G_2, and hence of inferring the average duration of each stage, depends on measuring the DNA content of each of a random sample of all non-S cells. On the average, those in G_2 will have twice the DNA content of those in G_1, but because of individual variation their measurements in fact overlap, causing quantitative ambiguity. A search routine for "maximum likelihood" estimation of G_1 and G_2 from as few as 200 such partially overlapping measurements has accordingly been specified and tested.

A computer facility was developed and applied to simulation of first-order physiological compartment kinetics. This will handle up to 20 compartments with pulsed, constant or continuously variable input. This facility may also be used to simulate transfer of biocides through an ecological system. Here, however, an assumption of constant transfer rates would be clearly unrealistic under Canadian climatic conditions. Provision has accordingly been made for possible independent cyclic seasonal variation, characterized by as many as four harmonics, in each transfer rate.

For large populations, of the order of one million or more, the effects of variation in individual cell transit times through each mitotic stage may be expeditiously computed actuarially, using transition probabilities as rates in a 4-dimensional "life table" having dimensions G_1, S, G_2 and M. This computation has been programmed and used to simulate feedback control of population size. If, as the reproductive population grows in number, a slowly increasing proportion of daughter cells is lost to it by differentiation, the dividing population will approach a limiting size

asympotically from below. If also DNA synthesis is inhibited in a size-dependent fraction of the reproductive population, leading to an accumulation of cells in G_1, a limiting size is approached via damped oscillations.

Publications of the Division of Biology, 1968–70

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The work of the Division continues to reflect its triple role as an information, advisory and research agency serving the construction industry of Canada. About 5,000 inquiries were answered during the past year from the Building Research Centre in Ottawa and from the regional offices of the Division at Vancouver, Saskatoon, Toronto and Halifax. Some 900,000 copies of publications of all kinds were distributed on request, more than half of these being accounted for by the monthly Canadian Building Digests, which are now becoming widely used in the teaching of building science and technology as well as in the industry generally.

The advisory role of the Division, though not clearly separable from information and research, continues to grow, and evidence of this is provided by the committee memberships of all kinds held by the Division, which now total 348. The 1970 edition of the National Building Code, in preparation for the past year and more, has represented a very substantial increase in this kind of activity on the part of the research officers who serve as technical advisers to

the various revision committees. This is in addition to the continuing work of the Codes Secretariat.

Assistance through committee service to the Standards work of such bodies as the Canadian Standards Association, the Canadian Government Specifications Board, and the American Society for Testing and Materials, continues to be a large and important part of the Division's activities. Despite the great need for more and better standards of all kinds in the building field, it is not possible to provide all the assistance required and many invitations to serve have to be declined.

The number of visitors coming for discussion of developments and trends in building has increased markedly during the past year. This is due in part to the generally increased interest in industrialization which is seen by many as a way of improving the industry and of reducing the cost of construction. The Division has continued to provide the opportunity for discussion, at the design stage of building, of the principles arising out of the steadily developing building science. Additional opportunities for communication of the results of research done in Canada and elsewhere are provided by the Building Science Seminars presented each year in Calgary and in Ottawa, the subjects of the most recent ones being air conditioning and durability of materials.

The research work, which feeds all other activities of the Division, has been pressed forward as vigorously as possible with current budget limitations and the many commitments in other directions. Work on high buildings, which is considered important because of the rapid increases in size and number of such structures, is being continued through the projects on wind loads, seismic response of structures and air movement in buildings. The latter assumed unusual importance during the year because of its close relation to smoke movement. A number of special studies with the computer were carried out on a priority basis for various operational configurations of typical high buildings as a contribution to the 1970 edition of the National Building Code.

The reorganization associated with the retirement of Dr. R. F. Legget, the first Director, recognized the expanding demands being made upon the Division, the Sections of the Division now being arranged in four groups. Two of these, on Building Practice and Codes and Standards, recognize two special areas of responsibility. The other two groups have been formed from the Laboratory Sections. The new Environmental Laboratory, now being equipped, represents a substantial addition to the Division's facilities and to the capability to evaluate building components and systems on a performance basis, in anticipation of new developments in the construction industry.

Building Materials Section

This Section represents an interdisciplinary group concerned with the study of the nature and behaviour of organic and inorganic building materials. All the research is problem-oriented with emphasis on the understanding of the processes involved in deterioration and change of properties under conditions of service. This report deals only with a part of the work in progress during this period.

Degradation of Organic Materials

Solar radiation is a major factor in the degradation processes when organic materials are exposed outdoors. In order to understand these processes and to simulate the radiation component of accelerated weathering machines, measurements of the intensity of terrestrial solar radiation have been made in Ottawa.

Measurements of the three parts of solar radiation, ultraviolet, visible light and near infrared, were made for three south-facing surfaces: vertical, 45 degrees from vertical and perpendicular to the sun's rays. Diurnal and seasonal changes of each radiation band were determined. As expected, the intensity of all bands was highest on the surface aimed directly at the sun and the variation during the day least. The intensity was lowest on the vertical surface while the diurnal change was greatest. On two surfaces ultraviolet radiation varied the most during either a day or a year followed by visible light and near infrared but on the vertical surface the order was reversed. The total solar radiation varied in composition from winter to summer as follows: ultraviolet, from 1 to 5 per cent; visible light, from 39 to 53 per cent; and near infrared, 60 to 42 per cent. These results will be related to the intensity of radiation from artificial light sources used in accelerated tests.

Sealants

The stresses to which sealants are subjected in use are indicated by the amount and rate of joint movements in actual buildings. Measurements on expansion joints of two buildings, therefore, have been recorded for over a year and the results statistically evaluated. In these two cases there was found to be a high degree of correlation between temperature changes and joint movement. In the summer the movements are also influenced by changes in relative humidity which tend to counteract the temperature-induced changes. Consequently, movements in summer are less per degree change than in winter. The thermal coefficient of expansion was calculated for the wall and compared with the coefficients for the wall components. The calculated coefficient was less than the published values indicating that there are restraints to free wall movement. The maximum movement in a 1-inch expansion joint was calculated to be about 25 per cent at the 95 per cent confidence level.

Tests are in progress to determine the effect of temperature on tensile properties of three different types of sealants.

Frost Action in Building Materials

Great progress has been made in developing practical means for the protection of concrete and brick from frost damage but several problems are still unsolved, causing considerable losses to the economy. It is clear that no significant improvement can be achieved without the thorough understanding of the mechanism of frost action in porous materials, which is the aim of a study being carried out in the Section.

Water in the cavities of porous bodies, such as concrete, remains in a liquid-like state at temperatures well below 0°C. The quantity of the water in the solid was found to depend on the prevailing relative humidity based upon the vapour pressure of undercooled water and not upon that of ice. The consequence of this is that, for thermodynamical reasons, the cooling of porous systems to temperatures below 0°C decreases the internal relative humidity; thus the material must lose water to be at equilibrium. Measurement of the volume changes and thermal effects suggests that damage occurs when the amount of water lost in a given time, by flow and distillation, is less than the amount that must be removed to maintain equilibrium. From this it follows that high porosity, high degree of saturation, high rate of cooling and low permeability adversely affect the frost resistance of materials, which conclusions are consistent with experience in the field.

The Nature of Hydrated Portland Cement

The main cementing constituent of concrete is calcium silicate hydrate (C-S-H) produced during hydration of portland cement. To realize the full potential in design and enable predictability of performance of concrete, it is essential to understand the nature of this hydrate.

This Section has developed a model for the C-S-H material which not only incorporates all known information from chemical, physical and mechanical properties but also, it is hoped, provides some understanding by which it will be possible to predict properties that will enable improvements to be made.

The model recognizes that C-S-H is unhomogeneous, poorly crystallized and of variable composition. This silicate which is a layered crystal and water, termed "interlayer water", occupies positions between these layers. Calcium ions also occupy positions between the layers. The model incorporates the idea that the amount of calcium and water between the layers can be altered by the conditions of preparation, such as water-to-cement ratio, temperature and admixture content, and explains most of the properties of practical importance through the layered nature of the silicate and the calcium and water between them.

It is recognized that the above nature of the material is unstable and changes in conditions such as drying and wetting, and application of stress, can cause changes leading to drying shrinkage, creep and other properties.

Based on the model, work is continuing, which it is hoped will lead to development of improved properties of concrete.

Building Physics Section

The work of the Section is concentrated on acoustics and vibration problems. Both laboratory research and selected field projects are undertaken, in order to link the work of the Section to the problems that occur in buildings. Because of the specialized nature of the work, an acoustical testing service is also provided to Canadian industry.

Dynamical Response of Structures

Studies are continuing on the influence of foundation conditions on the dynamical response of structures with the aim of finding a simple means of taking account of foundation compliance in the analysis of structures. The performance of composite structures in which the horizontal loads are shared between two systems, say a concrete core and a steel frame, has been studied analytically; this will be supplemented by measurements on suitable buildings. Measurements accumulated over some years on vibration levels in laboratory buildings have been analysed and combined with data from other sources to arrive at a set of vibration criteria for typical laboratories.

Vibrations and Building Damage

The effects of demolition operations on surrounding buildings have been investigated. Earlier work using blasting had shown the velocity of vibration to be the most useful parameter to correlate with building damage. These results were extrapolated to the more continuous sources used in demolition work and the results broadly confirmed the previously predicted damage threshold level.

Earthquake Load Requirements for 1970 Edition of the National Building Code

Considerable work has been done in implementing the proposals of the Canadian Committee on Earthquake Engineering for earthquake resistance requirements of the 1970 edition of the Code. In addition to the clauses in the Code proper, an extended commentary and bibliography was prepared as a Supplement to the Code.

Sound Insulation

A systems approach has been applied to the sound insulation problem where the nature of the sound

source, the directional properties of the incident sound field, the transmission loss of the barrier, and finally the effect of the transmitted sounds on the recipient have been investigated.

Spatial correlation of the sound field in a reverberant enclosure provides information on the departure of the field from perfect diffusivity. This information was used successfully to predict the sound insulation produced by the simplest types of partition (single-leaf walls). A number of more complicated and practical walls (double leaf walls) have been studied experimentally and this work, supplemented by theoretical studies of the various wall parameters, is leading to a more generalized theory of wall transmission.

The validity of the procedure for rating the insulation properties of walls, where in essence the transmission loss characteristic of a wall is compared with the characteristic of a hypothetical "ideal" wall, has been investigated using a subjective approach. Wall transmission characteristics were simulated by electrical filters; then the performance of various simulated walls, including the effects of low transmission loss in various frequency ranges, was rated by a jury panel.

Transportation Noise

Observations on the noise produced in railway coaches have confirmed the origin to be principally in the wheels' contact with the track. The noise might reach the interior either through the air and the coachwork or as structure-borne vibration conducted through the suspension. Measurements on typical constructions show the airborne sound to predominate, and modified designs for coach floors have been proposed.

Building Services Section

The Building Services Section is concerned with all the ramifications of controlling the temperature, humidity and air quality in buildings. The research projects, therefore, deal with the interactions between the inside environmental conditions, the performance of the building fabric and the environmental control equipment. These studies can be divided into two main categories:

(1) Those that are aimed at the development of improved methods and data for the design of building enclosures; and heating, ventilating and cooling systems.
(2) Those that involve the development of techniques for evaluating the performance of materials and assemblies.

Design Methods and Data

During the past year, there were three active projects in this category. One is aimed at the development of a method for predicting the conditions that will prevail in a building if a particular size and type of air conditioning system is installed and operated on a given schedule. This will be of immediate use to designers when they are selecting equipment for use in buildings. It is also the first stage of a long range program to develop improved methods for predicting the annual energy requirements for heating and cooling buildings.

Studies have been made of the stresses that can occur in both the inner and outer panes of sealed double glazing units when they are subjected to wind loads and uneven heating. The objective is to develop a sound basis for specifying the thickness of glass in different types and sizes of double glazing units. Some work was also done on determining the effect of the window frame on the surface temperature performance of unsealed double glazed windows. This work is being extended to include the effects of drapes and heating outlets on the thermal performance of windows.

The third project in this category is concerned with how smoke migrates through a building in the event of fire, and how the air handling system should be arranged so that it can keep refuge areas and exit ways free of smoke. There has been a great deal of concern about the danger from smoke in high rise buildings, and this project is intended to provide a basis for new regulations concerning smoke control measures.

Performance Evaluation Procedures

The Section has been involved for many years in the refinement of test procedures for measuring the heat, moisture and air transport characteristics of materials that are used in buildings. This work is carried on in co-operation with other laboratories by active participation in ASTM and CGSB committees. During the past year, a great deal of effort has gone into the planning of new facilities for measuring thermal conductivity, and facilities for evaluating the thermal performance and air and water leakage of wall-window assemblies. These facilities will be used to develop practical performance evaluation procedures, and to carry out a limited amount of development work for Canadian manufacturers.

Building Structures Section

The Section is concentrating on special areas of needed structural research, particularly studies of climate loads acting on buildings, and structural safety. Results of these studies are providing, in addition to information published in research and technical papers, material that serves as a basis for the refinement of the structural design part of the National Building Code.

Wind Effects on Building Structures

Wind pressure measurements on two full-scale office buildings in Montreal (33 and 45 storeys in height) have been carried out which serve as a basis for the evaluation of the results of wind tunnel studies and analytical methods of determining wind loads on

Low speed aeronautical wind tunnel modified by spires to create a turbulent shear flow simulating surface winds over model of downtown Montreal. Instrumented plexiglas model of a 600 ft. office building, on which full-scale pressure measurements have been taken, in centre. A cooperative project of Division of Building Research and National Aeronautical Establishment.

tall slender buildings. Wind tunnel studies on a scale model of the 45-storey building in Montreal and the surrounding area have been started as part of a co-operative project with the Low Speed Aerodynamics Section of the National Aeronautical Establishment (see photo).

For the full-scale measurements a new data acquisition system was obtained which records on computer compatible magnetic tape. This system is now being expanded to handle additional channels of input for the next phase of the field work, the instrumentation of a 58-storey building in Toronto.

The analysis of the records has provided general confirmation of the validity of recently developed analytical methods and wind tunnel modelling techniques. Five papers on experiences with wind pressure measurements on full-scale buildings have been presented or published recently.

Snow Loads

After the completion of a 10-year general survey of actual snow loads on roofs, which resulted among others in a joint Canadian-USSR paper, observations are now only taken in two special areas of interest. The first concerns loads on large flat, single and multi-level roofs, which are the most common type of roof on commercial and industrial buildings. These observations are providing further data on the contrast that usually exists between low *average* loads on exposed upper roofs, and high *peak* loads due to drifting on adjacent lower roofs. The second concerns the very high ground loads that accumulate at higher elevations in the mountains of Western Canada. A survey is being carried out with the help of DBR staff located at Rogers Pass, B.C. and Vancouver to provide information on the increase of ground snow load with increasing elevation above sea level at a number of sites.

Safety and Economy of Structures

As part of a continuing study on structural safety and economy closely tied to the National Building Code of Canada, two areas have been investigated: (i) the application of "limit state design" as a basis for structural calculations; (ii) probability studies in the areas of combined loads and structural resistance.

Limit state design contains two main improvements over existing allowable stress and plastic design. The first is a greater emphasis on the structural conditions ("limit states") to be designed for such as cracking, excessive deflection and collapse. The second advantage lies in the use of three sets of partial safety factors —one set for the loads, another for the material properties or dimensions, and a third factor which takes into account the consequences of failure and minor errors.

A study of the probability of failure under combined wind load and dead load was used to evaluate and suggest changes in existing safety provisions for stress reversal. A probabilistic study of bending strength and ductility ratio of reinforced concrete has been completed which will help to assess existing design provisions and safety factors.

Fire Research Section

Fire Endurance

To design a building compartment for sufficient fire endurance one has to have information on (i) the probable fire severity in the compartment when fire occurs, (ii) the mechanisms of those processes which affect the performance of the building elements (walls, floor, ceiling) of the compartment under fire exposure, and (iii) the thermal and rheological properties and microstructural characteristics of the component materials at room temperature and at elevated temperatures. The Fire Research Section continues to do research in connection with all three of these areas.

To provide a better insight into the nature of the relation between actual building fires and standard fire tests the heat balance in fire test furnaces has been the subject of a comprehensive study. An important mechanism that affects the performance of the boundary elements of a compartment in fire is the migration of moisture under the effect of temperature gradients. An experimental and theoretical investigation concerning this mechanism has recently been completed. A set of differential equations has been derived which, when solved together with the appropriate initial and boundary conditions, yields the complete moisture concentration, temperature and pressure history of a wet porous solid in a transient process. Parallel to this programme a large number of computer calculations have been performed, concerning the heat flow through concrete masonry units during standard fire exposure.

Research concerning the thermal and rheological properties of materials has been continued. In 1969 a comprehensive investigation into the tensile and creep properties of some structural and prestressing steels at elevated temperatures was completed. Some work concerning the thermal properties at elevated temperatures of concrete was concluded. Theoretical considerations have been developed which, together with some experimental data, make the assessment of the thermal characteristics of concrete possible.

Fire in High Buildings

Recognizing that, in a fire emergency, complete evacuation of a high building within any reasonable period is impracticable, attention has been directed towards studies of measures that might be employed to permit occupants to remain in a high building while fire fighting is in progress. The work of the Building Services Section has developed a better understanding of the stack effect that in cold weather creates condi-

tions that cause air to flow into the lower storeys and out of the upper storeys of a building. These studies have included measurement of air pressure differences in a number of high buildings in Ottawa and Montreal during the winter. In the event of fire, smoke will similarly pass through a building from lower to upper storeys under the influence of air pressure differences. Reports of fire incidents in high buildings have confirmed this and have shown that smoke will pass through stair and elevator shafts with all doors closed.

As a result of an intensive study in conjunction with the Building Services Section, suggested methods of smoke control have been developed. These relate to typical plans of high buildings and are examples of ways by which the problems of smoke movement can be overcome. Three basic approaches have been utilized. These are: mechanical injection of air to create favourable pressure differences; venting to the exterior; and vertical division of a building into two separate zones. It became apparent during the course of the studies that any control technique must be applied to the building as a whole, because any change in air pressure conditions in one part of the building will modify those in other parts.

Thermal Decomposition Products

Organic polymers such as plastics and cellulose undergo both decomposition and oxidation reactions in a fire. A better understanding of the chemistry of these reactions is needed in dealing with various aspects of fire research such as combustion, flame retardancy, and formation of smoke and toxic products. Studies on the mechanism of thermal decomposition of various polymers have therefore been undertaken.

The life hazard due to the toxic products depends on the nature of the gases given off, their concentration and the duration of exposure of the products to those trapped in a building. The Fire Section is engaged in studies on the quantitative analysis of toxic gases and vapours evolved from the combustion of polymers. Studies on the influence of flame retardants on the mechanism of thermal decomposition of polymers have also been started.

Geotechnical Section

During 1969, the Soil Mechanics Section and Snow and Ice Section of the Division were brought together to form the Geotechnical Section. This rearrangement followed the appointment of Mr. C. B. Crawford, Head of the former Soil Mechanics Section, as one of the two Assistant Directors of the Division. It reflects the growing integration that is occurring in Canada of studies of the properties of soil, rock, peat, permafrost, ice and snow, and the solution of engineering problems associated with them.

Geotechnology is a significant part of the engineering expertise of the construction industry. The general objective of the Geotechnical Section is to develop for this industry, knowledge and techniques necessary for sound geotechnical practice. The work of the Section is concentrated in three principal areas of interest: soils, permafrost, ice and snow.

A significant difference is often observed between predicted and actual behaviour in the field. This difference can result in monetary loss due to overconservative design, inappropriate construction practice and occasional failures. The Section has continued to emphasize field and laboratory studies designed to improve predictive capability.

Heave in Billings Shale

An unusual problem of shale expansion resulting in the heave of the basement floor of a three storey office building located in Ottawa, was investigated. Level surveys showed a total heave of about 3.8 inches in one area, and 2.2 inches in a second. The building was founded on the northern reaches of the Billings formation, a black pyritiferous and fissile shale.

Excavation and drilling showed that the shale had weathered to a depth of 2-1/2 to 3 ft. below the floor. Beneath the altered zone the shale was competent and extensively impregnated with pyrite veins. Most of the pyrite had disappeared in the altered zone, which now had a high content of jarosite, gypsum, bassanite, and smaller amounts of iron compounds. The shale in non-heaved areas contained very little visible pyrite.

The altered zones were highly acidic (pH ranging from 2.8 to 4.4) indicating that oxidation and weathering might be a biogenic process; elsewhere the pH was in excess of 7. Investigations by the Soil Research Institute, Canadian Department of Agriculture, established the presence of Thiobacillus Ferrooxidans. A study of the constituents of the altered zone indicated that these autotrophic bacteria were necessary for the chemical reactions that were taking place. It was shown that heaving occurred because the oxidation products had larger molar volumes than the original materials. Steps have been taken to break the chain of chemical reactions maintained by the bacteria, and they appear to have stopped the heaving.

Slope Stability

Landslides are a common feature in the slopes of stream valleys and terraces in the Leda clay deposits of Eastern Canada. These slides appear to be rotational slips which often retrogress a considerable distance into the slope, and in some instances become large flow slides. The slides occur at periods of exceptionally high groundwater, such as prevail during rapid snow melt, indicating that an ample water supply is a necessary condition for their initiation.

A complicating factor in the analysis of slopes of Leda clay is the presence of a weathered crust. The crust consists of at least two layers—an upper,

strongly oxidized crust, and a lower layer of grey clay that may be quite sensitive. The upper part of the crust is highly fissured and water moves freely through it.

In current studies of slope stability, the Section is investigating the shear strength of the clay in the range of low stress that exists in slopes. It was found that in this range of stress the behaviour was not that of an intact clay, but rather that of a predominately "frictional" material that dilates at low strains. This type of behaviour and its implications has not been considered in earlier studies of slope stability.

Frost Action

Studies are in progress on the vertical heaving forces exerted by freezing Leda clay on 3 1/2″ diameter steel pipes and a one foot diameter steel plate held in a fixed horizontal position at the ground surface by a reaction frame anchored in rock. The uplift force measured on the steel pipes was equivalent to a vertical shear stress of greater than 12.5 psi. applied over the surface of the pipe frozen to the ground; the vertical force exerted on the steel plate was in excess of 30,000 lbs.

Permafrost Distribution

Observations of the micro-climate and terrain factors affecting the occurrence and stability of permafrost are being carried out at Thompson, Man. At four undisturbed locations with different surface characteristics, measurements are being made of the air temperature, precipitation, snow depth and density, ground temperature, depth of freezing and thawing, wind velocity, net radiation and heat flow at the ground surface. Observations of the groundwater regime and detailed mapping of the sites will be carried out in 1970.

A comprehensive survey of the southern limits of the permafrost zone has been completed, and a survey of the distribution and nature of permafrost in the vicinity of the boundary between the continuous and discontinuous zones initiated. Thermocouples strings for measuring ground temperatures in the latter region are being installed at Yellowknife, Port Radium, and Rankin Inlet in the N.W.T., and at Churchill, Man. Attention is also being given to the characteristics of the permafrost in the Western Cordillera and in the high Arctic.

Permafrost Engineering

Studies to assess the effect of a large fill on permafrost were begun at the Inuvik Airport in 1957. Additional instrumentation was installed to determine the effect on ground temperature of paving the airstrip in 1969. Observations of ground temperature and settlement were continued at the town of Inuvik and at dykes constructed on permafrost near Kelsey in Northern Manitoba. A study of the field performance of different types of anchors in permafrost is being carried out at Thompson, Man.

Ice Engineering

An investigation of methods of predicting the date of break-up for lakes has been carried out over the past three years. It was found possible to predict the break-up date of small lakes with a standard error of 2.0 to 4.5 days using regression equations based on past break-up and air temperature records.

Observations were made of the deformation behaviour and strength of ice from the St. Lawrence River under conditions of constant rate of strain. These observations showed that a ductile-to-brittle transition occurs for ice at a strain rate of about 5×10^{-3} min.$^{-1}$. Information on the deformation characteristics of ice is required for determining the forces that ice can exert against structures.

Avalanches

Studies on avalanches are being carried out at Rogers Pass, B.C. The investigations have confirmed that the size of avalanches, as measured by the weight of snow contained in them, follows a log-normal frequency distribution at sites where several avalanches run each winter. Observations are also being made on the impact pressures caused by avalanches. Pressures ranging between 0.7 and 1.8 psi. have been observed for snow dust, and between 5 to 19 psi. for denser dry snow flowing along the surface.

Books

Two books on geotechnical subjects were published in 1969 in the Canadian Building Series of the University of Toronto Press. One was the MUSKEG ENGINEERING HANDBOOK prepared by the Muskeg Subcommittee of the NRC's Associate Committee on Geotechnical Research. This book was edited by I. MacFarlane, a member of the Geotechnical Section until July 1969. The second was PERMAFROST IN CANADA by Dr. R. J. E. Brown, a member of the Geotechnical Section.

Building Practice Group

The Building Practice Group was reorganized in 1968 with the aim of improving service to the construction industry. The work of the Group is now carried out through three technical sections:-

a) Construction Section, orientated to the technical research needs of the building contractor, with emphasis at present on two projects, winter construction and industrialized building.
b) Design Section, concerned with the development and application of design information to the practice of building.
c) Building Use Section, involved in studies of pro-

blems arising out of the Use and Occupancy Section of the National Building Code.

The work of the Library and Publications Section, which play an important role in the dissemination of information on building and in putting it to work, are included as part of the Building Practice Group.

Construction Section

Winter construction has become common-place in Canada and few inquiries are received from contractors in the technical aspects of winter work. There is, however, a continuing interest in the relative productivity of winter building as compared with summer work. Several studies were carried out in the field to determine the number of man hours required to carry out certain identical operations in summer as well as winter projects. The results indicate that productivity is influenced to a greater degree by unknown factors than by winter weather. Further studies will be undertaken at a later date to identify the unknowns.

Industrialized building is being introduced into North America. A survey of the state of the art on this continent has been carried out with particular emphasis on the Canadian situation where several European systems have been introduced. The results of this survey are being processed and a report prepared.

Design Section

The development of technical information and design principles relating to walls, roofs and other building elements is accomplished by observation of problems that develop in building, and by analysis of these in cooperation with the related specialists in other sections of the Division. Problems come to the attention of the Section through the handling of direct and written enquiries from all groups in the construction industry, with whom we have close liaison.

The promotion and application of information on service conditions, properties of materials and building science principles is undertaken through publications, lectures, seminars and in a direct consultation role with building owners, designers and builders.

Performance Studies

While the principal activity of the Section in 1968 and 1969 was the preparation and dissemination of information, some performance studies and field work were carried out. In the Ottawa area, in cooperation with the Building Services Section, the air leakage characteristics, the effect of ventilation, and the placement of insulation were examined in occupied houses having condensation problems in flat roof spaces. Alterations were made to some of the houses and the effects of the changes were examined. At the Montreal Road Laboratories site, a test building was constructed late in 1968 to further study the flat roof condensation problem under more controlled conditions. Studies were carried out for part of the winter of 1968–69 and were continued for 1969–70.

Observations of the comparative weathering of a variety of bituminous, plastic and rubber roofing systems continued during 1969. This project originated in 1964 with the Materials Section. A report on this project was prepared in 1969 for publication early in 1970.

Measurements of creep in the concrete frames of some Ottawa highrise buildings has been in progress for a number of years, and these were continued by the Design Section in 1968–69.

Some consideration was given to insulation, drainage and waterproofing of foundation walls, aimed at improving the environmental conditions under which such walls must function.

A number of reported cases of wall staining in electrically heated homes prompted a modest study to indicate the amount of air pollutants that might exist in homes heated electrically as compared to oil-fired furnaces.

A study of construction details of wood framed houses in the Ottawa area was continued as possible during the year and a photographic record is being prepared. Updating of a cost study of two wood-frame bungalows was continued as well.

All members of the Section have been involved in field studies of specific building problems that have been brought to the Division by owners, architects and builders. Help and advice was rendered where possible, and valuable feedback has resulted in some instances.

Roofs and Roof Terraces

During the past two years a new approach to the design of roof and roof terrace systems has been recommended. The principles to be followed involve protection of the waterproofing element and proper attention to the handling of moisture and in particular the drainage aspects of such systems.

Rain Deposit and Water Migration

An architectural student from Nova Scotia Technical College, employed as a summer worker in 1969, was able to make a start on a study of the hydraulics of exterior surfaces of buildings. Field observations of rain deposit, water migration and dirt marking were made for a number of buildings mostly in Ottawa. The results of the study were very interesting, and begin to give an understanding of building problems associated with water migration, and to suggest means to control them. It is hoped that the study can be continued and expanded at some future time.

Building Use Section

The Building Use Section was formed in 1968 to study problems arising in the revision of Part 3, Use and Occupancy, National Building Code. Succeeding revisions showed that more definitive information on the use of buildings was necessary to overcome difficulties which the use of the Code had revealed. Existing rules based on traditional plan forms became less able to accommodate new uses and changes in existing uses that are occurring. The traditional hazards are becoming less of a problem but new conditions raise the possibility of potential hazard, because they are not fully understood. Traditional rules have been imposed mainly as a result of tragic experience. The aim of the new Section is to forestall tragedies by providing knowledge so that controlling rules may keep step with evolving building use.

Remoteness of Exits

In 1969 the Building Use Section was engaged in assisting with the preparation of the 5th Edition of the National Building Code to be published in 1970. One matter of concern was the adaptation of egress requirements to "core" type buildings. Traditionally, building regulations have required that exits be remote from each other. This philosophy is inconsistent with the idea of a "core". The Building Use Section has established that "remoteness" in terms of life safety is associated with the route to travel between exits and not the direct distance between them. If this route is long enough, and is protected, the location of the exits is not significant. Acceptance of this idea in the 1970 edition opens the way for greater freedom of design without relaxing the standard of previous editions. Remoteness as related to the travel route had been proposed as early as 1964. The difficulty has always been to phrase the requirement to accommodate the variety of plans to which it would apply. To overcome this problem, among others, the Section has commenced a study of the geometry of plan arrangements. This study is still exploratory but has nevertheless assisted in achieving improved egress requirements in the Code.

Egress Requirements in University Residences

The National Building Code requires that from a door of a suite (or separately rented room) two separate paths of travel to separate exits must be provided. Questions have arisen as to how this is interpreted with respect to university residences. What is meant by a suite in such buildings? This problem is directly related to the characteristics of the occupancy. A study made in 1968 showed that patterns of individual and group student territory, and activity, as well as the physical plan arrangement were involved. In 1969 the study was carried a step further and a definition of a suite, related to the above three characteristics was proposed. A suite is a term used when the patterns of the three characteristics correspond.

Library

The Library of the Division of Building Research serves not only the needs of the Research staff of the Division but the needs of Engineering Consultants, Architects, Contractors, University Professors and Graduate School students across Canada. Like its parent, the National Science Library, it is an "information transferral agency" serving the needs of all Canada. It has links with other building information sources throughout the world. Librarians, documentalists, architects, engineers, management consultants and other research workers frequently visit and work in the Building Research Library to make use of its unique collection in several fields, such as its extensive collection of Scandinavian building reearch literature. Since the document collection is classified by the Universal Decimal Classification, the professional staff are frequently consulted for advice and help. Every two years the Building Research Library distributes its "Selected List of Books". In addition, the monthly bulletin "Recent Additions to the Building Research Library", is sent to 400 organizations and individuals. The Library also assists in the compilation of Canadian Building Abstracts which are published twice a year, and the Book Notes section of the Division of Building Research's quarterly "Building Research News".

Publications Section

The Publications Section is responsible for editing, processing and distributing the reports on the work and activities of the Division. As publications are one of the principal means by which the work of the Division becomes known to those in the construction industry and others interested in building, every effort is made to issue the information in ways that are appropriate to the many disciplines that are represented in this wide field.

The Section maintains mailing lists to provide those interested in building research with information on new publications or to provide copies as issued of certain series of publications. The number of copies of DBR publications distributed during 1968 was 845,775; in 1969 the number was 751,810. Fewer DBR publications were issued in 1969, which accounts for the drop in total distribution, and this decrease is attributed to the involvement of many DBR research officers during 1969 in the preparation of the extensively revised 1970 edition of the National Building Code of Canada.

DIVISION OF BUILDING RESEARCH

Codes and Standards Group

The Codes and Standards Group was established early in 1968 to co-ordinate the Division's services to the National Building Code of Canada and to undertake studies relating to the special needs of the Code. The Group comprises the Codes Secretariat which provides secretarial service to the Associate Committee on the National Building Code, and a special Technical Unit which has been concerned mainly with the housing needs of the Code and with providing technical assistance to CMHC and the NHBA. The Group also provides secretarial and organizational assistance to International Technical Meetings for which the NRC is the host agency.

Much of the activity during the past two years has been undertaken in direct support of the Committees responsible for the preparation of the 1970 edition of the National Building Code. A major project has been the preparation of a revised Part 9 which is to be renamed Housing and Small Buildings and which will be expanded to apply to most buildings up to 3 storeys in height and not more than 6,000 sq. ft. in single floor area. The new content is based on appropriate material for housing from the Residential Standards together with essential provisions from Part 3 for the other occupancies to be covered.

Other activities included participation in Committee studies relating to fire safety in high-rise buildings, the technical assessment of steel studs for partition and exterior wall construction, and arrangements for seminars on Canadian Housing Techniques for trade missions from overseas countries.

Atlantic Regional Station

This Station, in Halifax, maintains liaison with the Construction industry in the Atlantic Provinces. Attention is given to climate, economics, indigenous materials, and trade practices. There is increasing need to acquaint the industry with information from reliable sources, particularly the published findings of the "Building Center". Of special interest is the effect of regulations on the cost and performance of buildings and the trend to uniformity based on the National Building Code.

Laboratory projects relate to masonry and to wood moisture effects on coatings. Short-term projects, identifiable with field problems, continue but future planning relates more specifically to design and on-site practices influencing materials performance. Interest in factors affecting performance has resulted in instrumentation of buildings to record temperature and moisture in walls and roofs and the wetting of metal ties for precast components. Late in 1969 electrically heated portable classroom units were instrumented to record heat loss, temperature and relative humidity.

Coatings Performance

This subject included the observed performance of paint on wood sidings under various exposures. Co-operative programs involve a variety of buildings at Lighthouse Stations off the Nova Scotia coast and houses of 1947–48 vintage maintained by CMHC in New Brunswick. These studies have led to improved surface preparations and repainting systems in the interest of maintenance requirements. A laboratory experiment involving simulated wind-driven rain suggests little penetration beyond the paint film—wood surface interface under continuous wetting with apparent redistribution in the wood during drying cycles.

Housing

Close liaison exists with CMHC, Provincial Agencies, and industry on the technical and economic aspects of house construction. Recent approaches relate to "sweat equity" involving increased public interest in co-operative, shell, and expandable concepts. It is emphasized that the immediate optimum to production is somewhere between traditional "stick-built" and total factory fabrication. The cost of serviced land received special attention in seeking economic alternatives to traditional methods of installing services and determining sensible requirements. Recent interest by regional manufacturers has stressed the importance of the assessment and evaluation of new methods and materials.

Cold Weather Masonry

Suggestions that regulations regarding cold weather masonry are unnecessarily severe and observations of the excellence of traditional cold weather masonry, involving warm, dry materials, but no protection, led to an interest in this area. Field studies both locally and in Scandinavia, and the results of research in the latter countries, have led to a laboratory study of Scandinavian findings in terms of Canadian materials and practice. At this stage, it has been established that quality masonry can be laid up at temperatures well below the 40°F required in the NBC, provided certain basic requirements are met. It is equally evident that if the parameters are not understood and carefully recognized, serious problems can result.

Prairie Regional Station

The Prairie Regional Station provides a research and technical information service to the construction industry in the three Prairie provinces. Many inquiries on a wide variety of subjects related to building are handled by the Station. The research activities are specifically directed to problems of peculiar interest

within the region related to climate, geology and building practices.

Soils and Foundations

Extensive glacial deposits and a cool, dry continental climate combine to create serious foundation problems throughout the populated areas of the Prairie Provinces. Houses, light commercial and industrial buildings, and municipal services, such as sidewalks, roads, water and sewer lines, undergo large total and differential movements when carried on shallow foundations over glacial lake clays of large volume change potential. This volume change is closely related to moisture content change, which, in turn, is a function of the precipitation-evapotranspiration balance and man-made modifications in the natural environment. Current studies include the documentation of performance of conventional foundations and of new designs which give promise of improved performance.

Large structures which impose unusually heavy or rapidly changing stresses on various glacial deposits are also being studied. The rapid increase in number and size of high-rise buildings has indicated the need to undertake full-scale studies of the compression-consolidation characteristics of various glacial clays and tills. Large storage structures for grain, oil and minerals cause large and rapid changes in subsoil stress conditions. Some of these structures or their auxilliary equipment are sensitive to relatively small movements and this further accentuates the need for more complete knowledge of soil-structure interactions. Earth fill embankments are now being built to unprecedented heights for roads, railways, dams and recreational purposes. Some of these provide unique opportunities for study of the engineering properties of prairie soils.

Fine grained, poorly drained soils throughout the Prairies have concentrations of sulphates which are often hazardous to concretes. Although much is already known about design requirements for good concrete performance in such conditions, serious problems still plague many thousands of structures built in the recent past. Documentation of performance problems and work with standards-setting agencies will be necessary until the minimal requirements for long term durability are established and enforced.

Roofing Studies

A properly functioning flat roof system must provide protection against leakage of moisture into the building. Conventional systems normally include a built-up membrane, usually of bituminous material and several layers of felt, placed above an insulation. The latter rests on the roof deck, possibly with a vapor barrier interposed between them. Damage to the roof involves wetting of the insulation and breakdown of the top membrane. Research is being carried on at the outdoor exposure facility to assess the practicality of several methods of removing moisture from wet insulation and to study a relatively new system which is designed to avoid some of the weaknesses inherent in conventional systems. In the new design, the impermeable membrane is protected from sun, traffic, and temperature extremes by placing it below the insulation. Studies of thermal and physical performance of insulations under these conditions is being continued and work on membrane performance is being started.

This work requires the measurement of moisture content of materials and heat flow under somewhat special conditions. Consequently, it is necessary to conduct research and development to adapt existing methods to meet the requirements.

Humidity Measurement

The humidity calibration facilities at Saskatoon are used for calibration of a variety of types of hygrometric equipment. Twice yearly calibration of Dunmore type humidity sensors is carried out for a group of commercial firms who then use them as transfer standards. The equipment is also used for calibration of sensors for our own research work, and for evaluation of studies of commercial hygrometric equipment.

Recently completed research that was dependent on the facilities include a study of moisture absorption by wood, the use of sodium chloride as a heated electrical hygrometer, and a study of the humidity level in sealed double glazed windows.

British Columbia Regional Station

The B.C. Regional Station operates in conjunction with the B.C. Research Council at the University of B.C. The station provides a technical information service in the field of building. Most of the activity at the station involves the handling of inquiries received by telephone, mail and personal visits. Total inquiries in 1968 were 760 and 820 in 1969. In some cases field visits were made in an attempt to assist in the solving of performance problems. Questions arising from the extensive use of the National Building Code in B.C. comprise a high percentage of inquiries received.

Information dissemination was carried out largely through the presentation of talks and lectures to students in architecture, engineering and building technology, staffs of various public agencies, and trade and professional associations. An information display was manned at the first Western Construction Materials and Equipment Show held in Vancouver in November, 1969.

Toronto Information Office

This information office of the Division was established in 1967 to extend the liaison between the Building Research Centre in Ottawa and the construction industry in Metropolitan Toronto and the surrounding area. Its main purpose is to disseminate technical information and to assist with field observations and studies when the occasion arises. The interest in obtaining publications of the Division has shown a steady growth since this office was first opened.

During the past two years, as the presence of this office became better known to the professional offices associated with the building industry, the number of inquiries pertaining to buildings and their construction continued to increase. The National Building Code and National Fire Code remain the major sources for inquiries relating to their application. Other inquiries covered a wide range of interest from architects, consulting engineers and building contractors. A number of inquiries were received from material suppliers and manufacturers with regard to test methods for use in evaluating newly developed materials and building systems. Several field visits were made to examine problems that had been encountered with either walls, windows or roofs of buildings.

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In the two years that have elapsed since the N.R.C. Review was last published, the former Divisions of Pure Chemistry and Applied Chemistry have been re-combined and an Advisory Board has been established. These changes are sufficiently new that no major alterations in the program have resulted. However, sections dealing specifically with Physical-Organic Chemistry, Surface Chemistry and Low Temperature Calorimetry, Chemistry of Fats and Oils, and Thermodynamics of Surface Regions have either been terminated or amalgamated with other activities. Emphasis continues to be placed on encouraging publishable contributions to innovative science and engineering, and the relevance of the long term programs continues to receive considerable stress.

Contact with both national and foreign industry, and industrial participation in the work of the Division has been encouraging. Industrial acceptance of innovation will undoubtedly continue to be a slow process, compared with utilization of science to support existing procedures. However, it is of interest to note currently increasing industrial response to techniques that have been virtually unused for nearly 20 years. This response is in part a consequence of the high sensitivity to environmental quality that has recently developed.

The reports of individual sections follow.

Analytical Chemistry

Although the Section completed approximately 2500 samples during the year, the emphasis has been progressively shifting from quantity of routine analyses to the processing of more complex analytical problems. An increasingly larger part of the Section's activities has involved the development of more specialized techniques of analysis and in designing more efficient methods of solving the analytical problems that have been encountered in the progress of the Division's research. The Section's specialized analytical facilities have enabled it to solve a number of problems submitted by industry and assist a number of university and government laboratories.

Trace Analysis

The profound effects produced by trace impurities frequently interfere with many research programs and therefore make the determination of these impurities important even at low concentrations. The spark-source mass spectrograph has been particularly useful for this purpose since it is capable of detecting traces down to the parts per billion level. Modifications have been made to the densitometer by incorporating an analog system so that concentrations may be read out directly. In addition a cryosorption pump has been constructed and incorporated in the source which has reduced the background of atmospheric gases to approximately 0.1 ppm. thus permitting the determination of oxygen, nitrogen, carbon and silica to much lower levels. Since this has been the only instrument in Canada it has provided assistance in a number of industrial problems and to several university research programs. In this connection it has been extremely useful in establishing the quality of a number of products by one Canadian company which is specializing in the production of ultra-pure metals. Very thin films on metal surfaces have also been analysed, some of them less than 500 Å thick. Sometimes these have resulted from contamination, while in other cases they have been intentionally deposited in the manufacture of semiconductors.

Mineral Analyses

A variety of ores and mineral products were analysed during the year to provide guidance in process development. Most of these were process pulps and concentrates resulting from benefaction studies being carried on in the division and included products from such ores as iron, nickel, copper, gold, silver, molybdenum, bismuth and barium along with concentrates from laterites and low grade coal. In general, qualitative and quantitative work at low levels were achieved by optical emission spectroscopy. Higher concentrations were more precisely determined by X-ray fluorescence or by atomic absorption. Gold in ore tailings was determined down to 0.005 ounces per ton by atomic absorption, since this proved to be much more convenient and rapid than the traditional fire assay method.

The interest in the rare earth elements has been stimulated by the extensive use of two of them, europium and gadolinium in phosphors for colour television tubes. The Section has continued to work on problems connected with these metals. A method of determining individual rare earths in small quantities of their mixtures collected on millipore filters has been developed using X-ray fluorescence which has a detection limit of about 0.1 micrograms.

The analysis of thorium and rare earths in ores has been seriously handicapped by the excessive solubility of their oxalate salts. These have been traditionally used for the initial separation of the metals from their associated elements. The Section has studied the use of fluoride for this purpose and has found that it avoids this problem and has other advantages as well.

Industrial Materials

Problems from 12 industries were studied during the year, many of which required the use of the emission or the spark-source spectrograph. These included the production of ultra-pure metals, semiconductor devices and nuclear materials. A technique for determining traces of oxygen present in compounds used in the production of zirconium for fuel rods was developed. In conjunction with the laboratory of the Royal Canadian Mint, atomic absorption and emission spectrographic methods were modified so that they were suitable for the analysis of precious metals in plating liquors and plating sludges.

Although both infrared spectroscopy and gas chromatography were extensively used in organic analysis of materials for the division they were also used to solve industrial problems. The efficiency of a catalyst converter, which had been designed to remove harmful emission from automobile exhaust, was studied by gas chromatography. Also an infrared technique was developed to monitor the deuterium concentration in potassium di-deuterium orthophosphate which is being produced by a small Canadian company for "Q" switches for laser units.

Six university and six government laboratories were assisted with analyses, which included a newly discovered enzyme and a newly discovered mineral.

Chemical Engineering Section

Reverse Osmosis

This is a general separation process which consists in letting a fluid mixture flow under pressure over an appropriate porous membrane and collecting the membrane permeated fluid at the lower pressure; this permeator is enriched in one or more constituents

of the mixture. No heating of the membrane and no phase change are involved in this separation process. This technique is applicable for the separation, concentration, and fractionation of inorganic or organic, and ionic or non-ionic substances in aqueous or non-aqueous solutions, in liquid or gaseous phase.

Experimental and theoretical studies have been continued on the process using laboratory-made porous cellulose acetate membranes. Methods for the specification and prediction of performance of membranes and reverse osmosis systems have been established. A set of general equations has been derived for reverse osmosis process design; the utility of these equations for parametric studies on water desalination has been demonstrated. A back pressure treatment technique has been developed to increase the productivity of membranes without sacrificing separation. The technique has been found applicable for the enrichment of helium in natural gas, and the treatment of hard and waste waters.

A flat film module containing about 6 sq. ft. of membrane has been used to concentrate maple sap on a semi-continuous basis to a maximum of 30% (by weight of sucrose).

Particle Technology

Considerable effort has been expended in the beneficiation and balling of fine mesh coals. Samples from Eastern and Western Canada and the United States have been examined and, typically, material with 20–30% ash, 5–6% sulphur and 30% moisture has been upgraded to an easily handled, balled product with 5–8% ash, 2–3% sulphur and 10% or less moisture before thermal drying. A semi-pilot scale coal beneficiation model unit has also been operated for some time.

A balling drum capable of producing highly spherical shot in a narrow size range has been developed. For example, iron shot with a median size of 4.1 mm. in which 90% of the spheres were in the range 3.6 to 4.6 mm. is a typical product. A number of potential applications are envisaged.

Other topics of study in the area of size enlargement processes have been the drying conditions of agglomerates and their relationship to strength and homogeneity in the product and the effect of agglomeration on the drying and filtration of suspensions. Selective agglomeration has also been used to concentrate the brucitic fraction of brucitic limestone ores.

In the area of fluid-particle systems, an electroresistivity probe has been developed to study the bubbling behaviour of such systems. The nature of the bubbles in gas/solid and gas/liquid/solid fluidized beds is of fundamental importance in characterizing their behaviour.

Agglomeration and de-ashing of coal fines.

Previous work on the effect of internals on gas-fluidized systems has led to the development of a dense-phase vertical pneumatic conveying line and an improved theoretical understanding of conventional pneumatic conveying near the choking point.

In response to inquiries from drilling contractors, the program on inclined baffle settlers has been reactivated. This type of settler has the advantage of having high capacity per unit volume which is particularly important as mineral drilling is extended to more remote areas that can only be supplied by air freight.

Forest Fire Hazard Recorder

The prototype machine analog of the 1948 Forest Fire Hazard Tables as designed by the late Dr. D. F. Stedman was tested and modified. This recorder was designed to respond to various weather factors as does the forest floor and to record the Fire Hazard Index directly.

Chemical Spectroscopy

Raman Effect

The determination of absolute Raman intensity in the gas phase with mercury arc irradiation has been terminated and the results reviewed as pre-laser data.

Due to the increased sensitivity of the presently used argon laser over previous sources, Raman spectra have been obtained for several negative molecular ions doped in a variety of alkali halide single crystals. Enhanced intensity giving rise to the presence of several overtones in S_2^- and S_3^- in particular, is evidence of the so-called Resonance Raman effect. This effect in iodine gas at a pressure of 5 torr at room temperature led to a spectrum of iodine containing a progression to the 17th overtone. This effect is different from fluorescence and a comprehensive study on halogen gases has provided experimental criteria for distinguishing between resonance Raman effect and resonance fluorescence.

The determination of absolute intensities in the gas phase, gas to liquid intensity ratios, and solvent effect studies on intensity and depolarization ratio are being continued.

A new project on the Raman spectroscopy of water and aqueous solutions of biologically significant molecules has been initiated.

Recent acquisition of lasers with lines at 3600 Å and 6328 Å makes it possible to study scattering processes as a function of frequency of the incident light and to obtain spectra not observable with argon irradiation.

The data acquisition system for the Raman investigations has been installed and programs are being developed for calibration of frequency and determination of intensity and depolarization ratio.

Infrared

Vapor phase studies of hydrogen bonding in some carboxylic acids have been carried out using infrared techniques. Heats of dimerization were obtained for substituted acids which associated to give centrosymmetric cyclic dimers. The heats of dimerization were essentially unchanged and it was concluded that the effect of substitution on the donor properties of the carbonyl group was compensated by the increase in acceptor property of the hydroxyl group.

Vapor phase studies on other hydrogen bonded systems are being investigated by i.r., NMR and Raman techniques.

Nuclear Magnetic Resonance

The study of the chemical shift in gases as a function of pressure has been extended to include temperature studies. This was made possible by improving the accuracy of the sample preparation and handling technique as well as the design of a new sample tube. The new results on temperature dependence indicate that the screening is affected by short range repulsive forces.

The investigation of rotational isomerism in a substituted ethane by NMR has enabled studies of the solvent effect on the energy difference and barrier height to be accomplished. Direct measurement of a gauche coupling constant has been obtained in CHClBr-CHBrI.

Several hydrogen bonded gas phase systems have been studied and thermodynamic parameters such as ΔH, ΔS were determined.

A model has been proposed and tested for solvent effect of non-polar solutes in non-polar magnetically isotropic molecules in the liquid phase. Interest in the analysis of multiplet spectra is being maintained and a six spin system has been analyzed as well as cis/trans configuration about the double bond in aliphatic systems.

Colloids

This section explores the properties of finely divided matter and its aggregates. Two major activities are pursued.

(1) Dielectric and Nuclear Magnetic Resonance Studies

Extensive studies have been made of clathrate hydrates, solid systems which serve as physically well-defined models for study of the molecular interactions present in aqueous solutions and colloidal dispersions, and which are of physiological importance. Guest molecules are dispersed in almost spherical cages in lattices made up of water molecules which are orientationally disordered. Interactions between guest and water molecules are commonly so small that the guest molecules are found to be almost freely rotating, ex-

cept at very low temperatures where they undergo large amplitude rotational oscillations. An inference is that the quadrupole moment of water in ice-like surroundings is much less than in the isolated molecule. Among related studies, cubic ice prepared at high pressures was found to be essentially identical to ordinary hexagonal ice in its dielectric properties, and line shapes characteristic of the guest-molecule structure have been found in the low-temperature proton resonance spectra of molecules enclathrated in lattices of heavy water. An NMR study has been made of the motion of methanol in its solid phases.

(2) Fine Particle Technology

Much of the work on this subject centres about spherical agglomeration, a phenomenon that has been studied in the Section for more than ten years. The phenomenon may be simply described as the flocculation of suspended solids with critical quantities of a liquid that preferentially wets them, followed by mechanical compaction of the flocs to dense aggregates approximately spherical in shape. The applications of this agglomeration can be quite diverse and they include: (1) The preparation of spheres of uniform size, from pure iron powder that have sufficient green strength for handling; the spheres are subsequently sintered to densities approaching that of massive iron but retain the low hardness of pure iron. (2) The agglomeration of calcium sulphate in the wet phosphoric acid process to render it more readily separable from the liquid phase by physical methods. (3) The upgrading of Canadian coals to reduce the inorganic sulphur and ash constituents to acceptable limits. This last example illustrates a more general and more extensive program on mineral recovery from ore bodies where agglomeration procedures have special advantages.

Much of the work on agglomeration has been done jointly with the Chemical Engineering Section. In the case of the coal project, collaboration has extended to the Fuels Research Centre of the Department of Energy, Mines and Resources, and to the U.S. Bureau of Mines.

A second project in particle technology has involved the preparation of lignin in a dry form that will reinforce certain rubbers to approximately the same degree as the more expensive petroleum carbon blacks. This technically successful project has been carried out cooperatively with the High Polymer Section.

High Polymer Chemistry

Polymerization Studies

The catalytic systems of interest to the section involve organo-metallic compounds and Friedel-Crafts catalysts. With the former group of initiators the emphasis is on the investigation of reactions which can be used to produce polymers with special structures. The mechanism and efficiency of coupling of polymeric lithium compounds with mono and polyfunctional halides is being investigated to determine the best conditions for graft and "star" polymer formation. Conditions for formation and characterization of block co-polymers of styrene-isoprene and styrene-methyl methacrylate essentially free of contaminating homopolymers have been developed. The formation of block co-polymers where the polymer units are chemically strongly different is not possible by simple methods. A technique has been developed whereby a few divinyl benzene molecules can be added to polystyrene, or polydienes using organo-metallic catalysis. This pre-polymer can then be used to couple to monomers such as vinylacetate, vinylchloride or isobutene, using a different catalytic system. Other studies include the efficiency of various lithium based initiators and the mechanism of cross-linking reactions in systems containing styrene and divinyl benzene.

With acid catalysis (Lewis or Bronsted) the interaction of these materials with olefines to produce isomerization or low molecular weight polymers is being studied. Monomers involved are ethylene, propylene and the butenes. For example, the reaction of AsF_5 with ethylene to produce low molecular weight oils is being investigated. Similar experiments were earlier carried out on propylene using a BF_3 based catalyst. The addition of BF_3 and HBr to β-methylstyrene is also under investigation. In connection with this programme studies of the complexes formed and exchange reactions involved with compounds such as PF_5 and AsF_5 are being studied using n.m.r. techniques.

Physical Properties

A range of block co-polymers of styrene-isoprene of varying molecular weight and composition are being characterized, first of all with respect to their solution properties and later with regard to solid-state transitions. A similar study is being carried out on highly stereoregular forms of polymethyl methacrylate. N.m.r. techniques are used to characterize the microstructure of polymers produced by special catalytic systems and to investigate the nature of the active species in anionic polymerization.

Rubber Laboratory

This laboratory is involved in the preparation of standard rubber samples, the preparation of special rubber parts for other divisions and testing rubber samples submitted from various sources. A research project is also underway on methods of incorporation of dry lignin into rubber, to give acceptable reinforcement and as a substitute for carbon-black.

Kinetics, Photochemistry and Catalysis

Kinetics

Several reactions of interest for the understanding of the chemical processes which occur in the atmosphere and of hydrocarbon chemistry have been investigated. The rates of attack of ozone on a number of simple olefins in carbon tetrachloride solution were found to vary with olefin structure in a manner very similar to that found previously for the corresponding vapor-phase reactions. Internal olefins are more reactive than terminal olefins, in qualitative agreement with air-pollution studies at very low reactant concentrations, but the difference in reactivity is much smaller. Incorporation of chlorine atoms into olefin molecules causes a drastic decrease in the reaction rates, demonstrating a predominantly electrophilic role of ozone in these reactions.

Study of the behavior of the electronically excited singlet oxygen atoms (O^1D) has been extended to their reaction with isobutane and, in good agreement with the previous results obtained by different techniques, the rates of a number of their reactions have been determined relative to their attack on neopentane. It was shown that O^1D atoms are deactivated to the ground state oxygen atoms (O^3P) when they interact with CO, CO_2, N_2, and Xe, but are removed by reacting chemically with H_2, CH_4, and neopentane. The mechanism and the rates of attack of the O^3P atoms on simple alcohols have been determined. Mutually consistent relative rates of hydrogen atom attack on olefins have been obtained by three independent techniques and these values may now be regarded as well established. The rates of collisional deactivation of singlet methylene have been measured.

Photochemistry and Radiation Chemistry

Further progress has been made in clarifying the primary process events in the photolysis of hexafluoroacetone vapor following absorption in its $n\pi^*$ band centred at 3000 Å. Kinetic and spectroscopic data obtained over a very broad range of conditions of excitation indicate that molecules initially formed in high vibrational levels of the excited singlet state may, in the absence of collisions, either emit or cross to essentially unbound levels of the excited triplet state from which decomposition is inevitable. At high pressures of ketone, or of inert addends, collisions cause vibrational relaxation in the singlet state, by a multistage mechanism, before the crossing to the triplet state can occur. Triplet molecules so produced quickly equilibrate so that phosphorescence emission can be observed; decomposition can also occur from this triplet state but a thermal activation energy of about 16 kcal. $mole^{-1}$ is involved.

The rates of collisional energy transfer from the photoexcited benzene triplet ($^3B_{1u}$) and singlet ($^1B_{2u}$) to a series of mono- and diolefins have been determined.

A photochemical cyclodimerization of liquid 2-butene with complete retention of molecular configuration has been discovered. The distribution of the four 1,2,3,4-tetramethylcyclobutane isomers formed depends on whether cis or trans-2-butene, or a mixture of the two, is irradiated.

The photolysis of formamide vapor at 2062 Å has been studied in some detail at temperatures from 115 to 500°C. Three major primary processes were postulated, yielding $NH_3 + CO$, $NH_2 + CO + H$ and $H + NHCHO$ with quantum yields of 0.45, 0.35 and 0.22 respectively. These were followed by abstraction of H from formamide by NH_2 and H to yield the NH_3 and H_2 which with CO comprised the main reaction products. At temperatures above 200°C, a radical chain reaction set in, propagated by the decomposition of the carbamyl (NH_2CO) radical into $NH_2 + CO$. This decomposition was found to be pressure-dependent, and values of E_0 and E_∞ of 21.7 and 25.0 kcal/mole were estimated. The mercury-photosensitized decomposition of formamide vapor has also been studied briefly.

Development of flash apparatus with a time resolution of from approximately 5×10^{-5} to 5×10^{-7} sec and of related fast pulse technique for studying fast reactions in solution has been completed. The detection and study of a number of chemically and biologically interesting transient species has thus been made possible for the first time. In collaboration with the Division of Biology, triplet excited orotic acid and orotic acid ester have been firmly identified. The recent detection of triplet excited thymine in solution is of significance with respect to the nature of the lethal and mutagenic effects of ultraviolet light, and to the mechanisms for repair of radiation damage. Strong evidence has been obtained for excitation of an olefin-proton-N-nitrosopiperidine complex followed by rapid collapse of the complex to form an addition compound between N-nitrosopiperidine and olefin. Liquid phase flash photolysis studies on the chemistry of triplet excited acetone—a model system for aliphatic ketones—is being continued. The rates of self-quenching of triplet $\pi\pi^*$ aromatic ketones have been found to be in the region 10^5–10^7 M^{-1} sec^{-1} contrary to the values in the literature. The results cast some doubt on the significance of triplet excimer in solution at room temperature.

A study of the radiation-induced isotopic exchange in H_2-D_2 mixtures has been completed. G-values as high as 1.3×10^8 were observed, and by using an electric field to remove ions in competition with the ionic chain reaction which causes the isotopic mixing, an average value of the rate constant for the chain-propagating step, $H_3^+ + D_2 \rightarrow H_2 + HD_2^+$ (and its isotopic variants) of 3.3×10^{-10} cc. $mole^{-1}$ sec^{-1} was estimated.

A re-examination of the radiation-induced isotopic exchange in $^{14}N_2$-$^{15}N_2$ mixtures has been undertaken with rigorous control of trace impurities, and G-

values appreciably higher than those obtained previously have been found.

The effect of electric fields on the radiolysis of acetylene is being investigated in an attempt to distinguish between ionic and non-ionic mechanisms.

Mass Spectrometry and Electron Impact Phenomena

Ionization studies with the electron monochromator have been continued. Using an electron beam with an energy spread of 0.06 volt the threshold ionization efficiency curves for C_1-C_4 alkyl radicals, allyl, benzyl, vinyl, and phosphinyl radicals have been obtained. From these measurements, improved values of ionization potentials and ionic heats of formation have been obtained.

Considerable progress has been achieved in the study of the mechanism of energy transfer processes involving ions, electrons and excited atoms in the D.C. glow discharge of rare gases and in the study of the negative glow as a model for investigating ion-molecule reactions in radiation chemistry. However, this project has now been terminated because of the limited value of the results obtained by the presently available techniques by comparison with the much more powerful recent instrumental innovations for studies in this field. Research in an alternate area, high temperature mass spectrometry, will therefore be intensified. Work is now in progress with the construction of a device combining a Knudsen vaporizer with a specially designed high sensitivity, medium resolution mass spectrometer, which will be capable of operating at a maximum temperature in excess of 2000°C. It is proposed to investigate the vaporization processes occurring in semiconductor materials which are relatively stable at high temperatures with the object of determining such thermodynamic properties as dissociation energies, heats of vaporization and phase transitions. The work will be carried out in collaboration with the Metallurgical Section.

Catalysis

The catalytic activity of sulfur free radicals present in natural zeolites and introduced by impregnation into synthetic zeolites has been studied with simultaneous determination of the type and intensity of the electron spin resonance spectra. A correspondence between the sulfur free radicals present in the catalyst and their "free-radical type" of hydrocarbon cracking has been found. The sulfur free radicals present, for example, in ultramarine, and in some of the sulfur impregnated synthetic zeolites responsible for their deep blue color, have been identified as S_3^-.

Paramagnetic resonance spectra of several free radicals introduced as impurities into alkali halide crystals have been observed. These include S^-, O^-, N_2^-, and NO_2^-.

The application of the temperature programmed desorption technique (TPD) to the study of surface properties of different catalysts has been continued. Deuteration of ethylene on alumina was extensively investigated. It has been found that on the weaker adsorption sites hydrogen atoms add symmetrically to the double bond by the Twigg-Rideal mechanism, while the rate determining step on the stronger sites is the addition of H atoms to ethyl radicals. The TPD technique was also applied successfullly to a metal catalyst, silica-supported platinum, on which a detailed study of adsorption and reaction of ethylene was made.

Fundamental aspects of dynamic adsorption equilibria on catalysts has been studied and a useful method for the evaluation of the net rates of adsorption and desorption from simple adsorption time measurements was developed.

High Pressure

This section has two main interests, the application of high-pressure techniques in physica! chemistry, and low-frequency spectroscopy. The two techniques are closely linked in that the effect of pressure is to squeeze molecules closer together against the intermolecular forces and the low-frequency spectroscopy is concerned with the intermolecular vibrations for which the restoring forces are the intermolecular forces. Frequently, the low-frequency spectroscopy is used as a technique for investigating high-pressure phases. A number of lines of work are being carried on at the present time.

Chemical Kinetics

The use of entropies of activation at constant volume as opposed to the more usual constant pressure is being explored. Measurements have been made of the effect of pressure on the rate of the alkaline hydrolysis of ethyl acetate in acetone-water mixtures and of the spontaneous solvolysis of benzyl chloride in glycerol-water mixtures. There is good evidence that the constant-volume condition provides a simpler view of the fundamental processes. An attempt is being made to measure the heat capacity of activation at constant volume for the hydrolysis of alkyl bromides.

Some preliminary and exploratory measurements of reaction kinetics up to 45 kbar have been made.

Thermodynamics of Liquids and Gases

The measurements of the equation of state of water are continuing. Measurements in the range 150 to 350°C up to 1000 bar have been completed, and the volume of the vessel in this temperature range is now being measured by a gas-expansion technique. It is frequently believed that hot water freezes faster than cold. This has been shown to be true under certain conditions. Water initially hot will lose water by evaporation faster than water initially cold, and the smaller amount left may freeze faster. The speed of sound in water has been measured accurately by

several persons recently; the measurements have been analyzed to yield the isothermal compressibility with a standard error of 0.002×10^{-6} bar^{-1}. A table of the best values of the isothermal compressibility at 1 atm in the range of –20 to 110°C based on these and our own PVT measurements has been prepared.

Transformations in Ice

Several phases of ice are orientationally disordered both at high temperatures and when quenched to 77°K. According to the Third Law, at low enough temperatures they tend to become ordered. A search is being made for ordering transformations in ice I, V, and VI. The method is one developed in this laboratory; it is to measure the high-frequency dielectric constant with a reproducibility of about 1 or 2 parts per million. A theory has been worked out that suggests that it should change by a few percent at an ordering transformation, and so transformations that take many years to complete should be detectable in a few days.

Ice IV is a metastable phase in the region of ice V, and only two other laboratories have succeeded in making it. Single crystal and polycrystal ice IV has been made and is being examined by X-ray powder and single crystal methods in collaboration with the X-ray laboratory, and by infrared spectroscopy.

Far-infrared Spectroscopy

The main lines of work in this field at present are the intensity of absorption by the intermolecular vibrations of molecular crystals and the far-infrared spectra of disordered solids.

The far-infrared spectrum of crystalline methanol has been measured and a normal coordinate analysis made. The intensity of absorption by solid chlorine has been measured.

Most of the work however has been on disordered solids. The infrared spectrum of perfect crystals is well understood in principle. Only about 1 in 10^{24} of the normal vibrations can absorb light as fundamentals. The world however is not made of perfect crystals, and many interesting substances like glasses, many polymers both natural and synthetic, and other substances that are scientifically and industrially important are not crystalline at all. An experimental program firmly tied to theory is underway. In these substances, all vibrations—about 10^{25}—are infrared active. The spectrum of the orientationally disordered ice I provides a good starting point, and following earlier work, the intensity of the far-infrared spectrum has been measured and interpreted in terms of the dipole-moment derivative of the hydrogen bond. This is the first measurement of the change of the dipole moment with the length of a hydrogen bond. At frequencies below about 40 cm^{-1} the sound waves were predicted and found to absorb light. This is of direct practical interest in that radar is used for measuring the depths of glaciers.

A factor limiting the application of the technique is the absorption of the microwaves by the ice. The microwave and the far-infrared absorption appear to have essentially the same origin. The theory of absorption by orientationally disordered crystals has been extended to take account of the correlation of the orientations. The far-infrared spectrum of vitreous silica has been measured down to 12 cm^{-1} and a detailed interpretation worked out. A lamellar grating spectrometer has been acquired and will be used down to about 3 cm^{-1}.

Dielectric Properties under Pressure

The static dielectric constant of water is being measured at pressures up to 10 kbar. A novel dielectric cell has been designed that is made of glass, but has no sealed-in electrical leads. This avoids the cracking of the glass that occurs when glass-metal seals are taken beyond about 5 kbar. Measurements have also been made of the effect of pressure on the dielectric relaxation of methyl cyanide in methyl cyanide quinol clathrate.

Hydrocarbon Chemistry

This Section is principally concerned with the liquid phase oxidation of hydrocarbons and other organic materials with molecular oxygen. Attention has been directed to the products, to the kinetics and to the mechanisms of these reactions.

Electron spin resonance methods and the rotating sector technique have been used to measure the absolute rate constants for chain propagation and chain termination in the autoxidation of a large number of hydrocarbons, ethers, aldehydes, alcohols, ketones, esters, halogenated compounds, sulfur containing compounds, etc. The reactivities of these compounds towards specific peroxy radicals have been correlated with their structure. It has also been found that not all peroxy radicals are of equal reactivity towards a specific substrate. This discovery explains why aldehydes are formed in significant quantities in oxidizing olefins. Aldehydes are responsible for many of the off-odors and flavors of rancid foods. The results of our work on absolute rate constants for autoxidation are proving useful in predicting the optimum conditions for some commercial oxidation processes and in predicting the oxidation characteristics of complex mixtures of organic compounds.

The role of antioxidants in retarding the autoxidation of organic materials has been examined both kinetically and by identifying the products formed from the antioxidants. Our latest work in this area involved the identification of the products formed from N-phenyl-2-naphthylamine (an antioxidant

commonly employed in rubber). This work represents the first successful product study on an amine antioxidant.

In addition to work on autoxidation, a number of other free-radical chain reactions have been studied. These include the reaction of triethyltin hydrides with alkyl halides, with disulfides and with per-esters. The formation of nitroxide radicals in amine inhibited autoxidations and the self-reaction of nitroxide radicals and peroxy radicals have also been studied.

The barriers to rotation about the carbon-nitrogen bond in a number of N-substituted anilines have been examined by n.m.r.

Metallic Corrosion and Oxidation

The electrochemistry of corrosion, kinetics of metal oxidation, and examination of surfaces by electron optical techniques are the three main areas of research. Consulting on corrosion problems is the other major activity. Enquiries were answered from various Canadian industries and government agencies. Consultation continued on examining thin film electronic devices for Northern Electric Research Laboratory and on corrosion in atomic energy and heavy water production.

Electrochemistry

Investigation of metal passivity was continued by studies of anodic oxide films. Cathodic reduction of anodically deposited γ-FeO(OH) differs from films formed by direct oxidation of iron. The γ-FeO (OH) reduces to give Fe^{++} both in solution and in the film, whereas the γ-Fe_2O_3 formed during direct oxidation reduces to Fe^{++} in the solution only.

Anodic oxidation of iron in de-aerated neutral sulphate solutions, initially containing no iron, showed the passivation characteristics to be very sensitive to prior air-formed oxide. Even a very thin initial film leads to reproducible passive behaviour at high potentials; at lower potentials, passivity gives way to pitting corrosion. The passive state and the mechanism of its breakdown are being studied also by electron-optical and radiotracer methods.

Oxidation of Iron and Nickel

The oxidation kinetics of annealed and cold-worked nickel was investigated from 700 to 1300°C. Oxidation is faster for cold-worked nickel, especially at the start, because of finer grain size in the oxide layer. The grain boundaries act as preferred paths for diffusion of nickel through the oxide; hence, the finer the grain size the greater the oxidation rate constant. This effect and the increase in oxide grain size with time and temperature are reflected in the activation energy which is high at high temperatures and long times, consistent with oxide thickening by lattice diffusion, and low at lower temperatures and short times, indicating diffusion predominantly via leakage paths.

The oxidation of iron at 10^{-6} to 760 torr oxygen was studied from 450° to 550°C using an ultrahigh vacuum micro-balance apparatus. Up to 10^{-5} torr an adherent layer of Fe_3O_4 formed. Above 10^{-4} torr, where Fe_3O_4 and Fe_2O_3 both formed, separation of oxide from metal took place as the result of the condensation of cation vacancies at the oxide-metal interface to form voids. Oxidation kinetics were strongly dependent on oxygen pressure.

The oxidation of nickel is being investigated in the same apparatus. Because experiments revealed that contamination of the nickel surface by silicon and carbon could occur under some conditions, the mechanism of this contamination and procedures to avoid it are being studied.

An ultrahigh vacuum manometric apparatus was constructed for measuring the growth kinetics of very thin oxide films, from a chemisorbed layer to a few thousand angstroms. It is being used to measure the oxidation of polycrystalline and single crystal nickel from 25° to 600°C.

Electron Optical Studies

Development of X-ray emission spectroscopy for examining surface and thin-film phenomena was continued in conjunction with ultrahigh vacuum electron diffraction. A low energy (500–2000 ev) electron gun was added to permit the study of characteristic soft X-ray emission. Calibration tests established that elements such as boron, carbon, nitrogen, oxygen, and sulphur can be determined at levels as low as 1/10 of a monolayer. Combined electron diffraction and X-ray emission studies have been directed at producing "clean" surfaces on tantalum, iron, and nickel and studying their oxidation in the 0–50 Å range of oxide thickness. Sub-monolayer quantities of impurities such as carbon alter both the oxidation kinetics and the crystallographic orientation of the oxide.

This apparatus has been used extensively for the analysis of thin film materials currently being developed by several Canadian electronics and metallurgical manufacturers.

Metallurgical Chemistry

Physical Chemical Properties of Metals

A reinvestigation of the lithium-indium phase diagram has shown the presence of a number of new intermetallic compounds. Some metallography was carried on but the principal tools were thermal analysis and X-ray diffraction analysis. The latter is being continued to clear up some doubtful results and uncertain areas of the diagram.

With the assistance of a Fellow supported by the International Atomic Energy Agency, a study of the diffusion of silver into aluminum has been undertaken, using Ag^{110} as the radioactive tracer. The problem of achieving an intimate intermetallic bond between the metals, free of any significant oxide film, appears to have been solved, and some preliminary results have been obtained.

Low Temperature Calorimetry

The study of the state of adsorbates on homogeneous surfaces is in progress. The adsorption of neon on a high surface area graphitized carbon has been studied. Heat capacities were measured in the temperature range from 1.5° to 30°K for two different surface coverages, namely 0.5 and 1.5 statistical monolayers. Also the heats of adsorption, the isotherm at 29°K and the isosteres at these coverages have been determined.

These measurements have disclosed important information concerning the state of the adsorbate. At temperatures close to the boiling point, adsorbed neon has a liquid-like structure. Till now a mobile gas-like structure has been assumed for this adsorbate at these temperatures. As the temperature is decreased the adsorbate undergoes a phase transformation. This transformation does not take place at a unique temperature but extends over a temperature range which is different at different coverages. The observed heat of transformation depends on the coverage and is lower than that of the bulk liquid to solid transformation. At temperatures below the transformation temperature range the adsorbate is in a localized state which is different from that of the bulk state. The low temperature measurements have shown clearly that the surface field of the graphitized carbon extends beyond the two statistical monolayers. Further work is now being carried out to determine the extent and the manner in which the potential field of the surface influences the structure of the adsorbed films.

The low temperature heat capacities of neon on graphitized carbon are the first ones which have been obtained for an adsorbate other than helium at liquid helium temperatures. The low equilibrium pressures of the adsorbates at these temperatures, except in the case of adsorbed helium, require cryostats which can maintain refrigerants for long periods of time, and temperature measurements should be taken to a high degree of precision. Both these requirements have been met in this laboratory.

X-Ray Diffraction

A greater interest in the detailed crystal structures of compounds under study in the Division (e.g., catalysts, binary rare earth alloys and high-pressure phases) has led to the setting up of an automatic diffractometer. A cooling apparatus, based on those already being used for photographic studies, is being constructed for this diffractometer and this apparatus will be used in studies of the compounds already mentioned. For example, it is hoped that a knowledge of the atom positions in the low-temperature catalyst will aid in understanding the mechanism of its operation. As in previous years a major portion of the work has been carried out in cooperation with other groups, namely the studies on rare earth-VB compounds, In-Li alloys, high-pressure phases and low-temperature clathrates in the ethanol-water system.

Electrical and Magnetic Properties of Metals

The insufficient knowledge of the fundamental motion of electrons in metals is a problem in the development of various aspects of metallurgy, including such as power transmission, metallic catalysis, as well as the atomic theory of alloy formation. Being quantum particles, the electrons cannot be studied by a direct microscopic examination and it becomes essential to make an indirect approach through the study of the consequences of electronic motion.

Systematic studies of this type which have either been completed or are under way in the group are notably of the Hall effect, electrical resistance, thermopower and magnetic properties of systems based upon the group 1B metals, Al or Ni. For example, recent measurements of the Hall effect in Cu single crystals containing a few parts per million of a foreign element have led to new information about the anisotropic interaction between the electrons and the localized foreign element.

Solid State Inorganic Chemistry

The binary systems of rare earth elements with arsenic, antimony and bismuth are being studied. The work includes preparative problems, phase analysis, crystallography and crystal chemistry on numerous intermetallic compounds which are of interest in the general field of solid state science and many of which are of potential value in the solid state device field.

A variety of topics associated with crystal growth and perfection are under investigation. The nature and origin of imperfections in large melt-grown arsenic crystals are being determined. Vapour transport reactions continue to be used to grow crystals of binary intermetallic compounds but the general applicability of the process is limited by the inadequacy of present knowledge. The transport mechanism is being studied by a combination of high temperature U.V. spectroscopy and closed system total pressure measurements. The thermodynamic studies on the high temperature equilibria are further augmented by the application of mass spectrometry.

Molecular Structures

Electron Spin Resonance

The study of environmental effects on the EPR spectra of aromatic radicals in solution has been continued. Previously measured variations in the coupling constants of the neutral non-polar radicals, phenalenyl and triphenylmethyl, have been shown to

depend on the volume polarizability of the solvent. A possible mechanism involves a shift in the energies of levels used in the perturbation description of σ-π interactions. The direct effect of temperature on the coupling constants of a series of neutral and ionic hydrocarbon radicals has been measured. The temperature coefficients have been shown to result from out-of-plane CH vibrations. Measurements and literature values of proton-to-deuteron coupling constant ratios confirm this result and in some cases provide an estimate of the vibrational frequency. Small contributions to the temperature coefficient arise from spin densities on carbons bonded to the CH fragment in question.

Several new radicals have been prepared and their spectra interpreted. These include benzo [cd] pyrenyl, phenalene anion, phenalenyl dimer cation and perylene dimer cation. The second of these radicals shows an alternating linewidth phenomenon while at low temperatures, where the conformers are frozen out, the γ-protons become inequivalent. The heat of dissociation of the last radical listed has been estimated from the temperature dependence of the spectra.

With the aid of a commercial liquid helium cryostat the paramagnetic resonance of crystalline pyrene$_2^+$ perchlorate, perylene$_2^+$ perchlorate and azulene$_2^+$ perchlorate have been measured. These represent a new class of organic paramagnetic crystal within the classification of Nordio, Soos and McConnell. From these results it has been shown that two types of spin may be present. At low temperature there is a component which is probably connected with lattice defects but shows considerable exchange narrowing. At higher temperatures the first two compounds yield a component resulting from thermal excitation of triplet excitons. The activation energy for the process was determined in both cases.

Nuclear Magnetic Resonance

A broad line NMR spectrometer has been developed using a 45 kG superconducting magnet. The spectrometer has considerable versatility; for example different nuclei may be studied with only slight instrument modification. At present the properties of organic ions both in solution and in the crystalline form are under investigation, the results being compared to those obtained from ESR and optical techniques.

Organic Crystal Semiconductors

Investigations of the optical and electrical properties of molecular crystals in general, and anthracene in particular, have continued. Measurements of the polarised Singlet → Triplet high resolution absorption spectra of anthracene-h_{10} and -d_{10} crystals have shown that considerable changes occur with temperature in the Franck-Condon overlap factors. These changes are found to be primarily due to variations of the C-C bond order, and their presence is particularly significant with regard to studies of the crystal triplet state. Other optical studies recently undertaken include measurements of the anthracene singlet exciton lifetime, from 350°–1.2°K, where results showed the lifetime variation agreed with theoretical predictions when particular care was taken to account for fluorescence reabsorption.

Greater emphasis has recently been placed on the study of the electrical properties of anthracene. Two new solid electrode systems have been developed, which are able efficiently to inject holes and electrons into anthracene crystals. Using these electrodes individually, single carrier properties such as carrier mobility have been studied over a considerable temperature range, 350–100°K. Due to the efficiency of these electrodes, measuring techniques based on the concepts of space charge limited currents could be used, though previous SCLC measurements were confined to ~300°K. Furthermore it was found that when opposing this new electron injecting contact, many electrode materials normally inert became efficient hole injecting contacts. Using this result it has been possible to develop an electroluminescent diode having a rectification factor $\sim 10^4$ and an electroluminescence efficiency of ~10%. The electroluminescence wavelength is not confined to that characteristic of anthracene, since, by doping, the emission spectra of the dopant is observed. Also, other aromatic hydrocarbons may be used instead of anthracene. Further investigations concerning possible technical applications of these systems are in progress.

Organic Spectrochemistry

Infrared Photometry

This Section has become increasingly involved with the development of computer-based techniques for improving the accuracy of infrared spectrophotometers. This work is being pursued under the auspices of the Commission on Molecular Structure and Spectroscopy of the International Union of Pure and Applied Chemistry. The use of high speed rotating sectors for the calibration of optical null-type infrared spectrophotometers has also been investigated. The computer programs developed for these purposes have been published and a photoelectric photometer for the primary calibration of the rotating sectors has been constructed. The Section has assisted several university and industrial laboratories in Canada and elsewhere to set up similar facilities and has provided a sector calibration service.

There are intrinsic limitations associated with the use of the conventional optical null photometric system and the Section has recently acquired a ratio recording infrared spectrophotometer of advanced design with a potential capability of much higher photometric accuracy. This instrument will use an incremental magnetic tape recording system. In con-

junction with the computer based methods of data analysis an absolute photometric accuracy of ±0.1% T should be attained, associated with high thermal stability and freedom from sample re-radiation.

This instrument will open up several new areas of interest. Among these will be the measurement of infrared spectra of trace amounts of materials in the presence of other species which absorb strongly in the same spectral range. Of particular interest are infrared spectra of molecules containing non-normal isotopic species at low enrichment levels, particularly ^{15}N and ^{18}O. These spectra are needed in connection with the vibrational analysis of complex molecules. Current studies of the vibrational motions of substances related to natural products have been limited by the lack of information about the spectra of O^{18} substituted species.

Infrared Spectra of Liquid Films

The measurement of the infrared spectra of thin films of liquids has special significance in connection with the interpretation of molecular motion in the liquid state. Currently there are serious difficulties in measuring the infrared absorption of thin layers of strongly absorbing liquids. Methods have therefore been developed in a number of laboratories to obtain such data from reflection measurements. An infrared refractometer is being constructed in our laboratory for this purpose. A complementary study is also being made of the transmission through thin layers of liquids using a cell of new design. Computer programs have been developed to correct such transmission measurements for the band shape distortions that arise where the path length in the liquid is comparable with the wavelength. These programs permit the computation of the optical constants (n and k) from which both the transmission and reflection behavior of the liquid can be obtained. One of the objectives of this work is to establish a transmission and reflection intensity standard. Once this is available it becomes possible to obtain the optical constants directly from routine measurements on conventional infrared spectrophotometers.

Specifications for Infrared Spectra for Documentation Purposes

The Section is also active in association with the IUPAC Molecular Spectroscopy Commission and the Committee on Data for Science and Technology of ICSU in formulating specifications for infrared spectra for reference purposes, and in the evaluation of computer-based techniques for the search and retrieval of infrared spectra from data banks by pattern recognition methods.

Organic Synthesis

A reinvestigation of the Polonovski reaction was carried out to determine whether deuterated trimethylamine could be utilized to prepare deuterated dimethylamine and formaldehyde. A convenient method of preparing these two compounds in 65–70% yields resulted from this study. In addition, new information about the mechanism of the Polonovski reaction was obtained through the isolation and identification of previously unobserved by-products.

A series of new β-hydroxyketones, $CH_3C(OH)RCH_2COCH_3$, was synthesized and cyclodehydrated with ring closure in excellent yields to substituted di-, tri- and tetramethylnaphthalenes and phenanthrenes, some of which are new while others are obtained much more easily than by previous methods.

The hydrocarbon, 1,3,4,6,7,9-hexamethylphenalene, was synthesized for the first time from 1,3,6,8-tetra-methylnaphthalene; it is of interest because it is the only substituted phenalene so far prepared that is capable of forming symmetrical ions.

A new and shorter synthesis of dimethylphenanthrenes has been developed, based on an extension of our earlier work on the action of Grignard reagents on β-diketones.

A simple method has been developed for replacing H for D in the methyl groups of polymethylbenzenes, naphthalenes and phenanthrenes by exchange with deuterated dimethyl sulfoxide.

3-deuteriocyclopentanone and cyclopentanone-^{19}O were synthesized for the first time for Raman studies by the Organic Spectrochemistry Section.

A simple and inexpensive method was developed for preparing deuteriobromic acid from deuterium oxide, bromine and sulfur.

Textile Chemistry Section

In the investigation of various aspects of fiber science, we are concerned primarily with providing a better understanding of polymer, fiber and fabric properties—how to measure, evaluate and improve these. In this context, the current research in the Section can be summarized in the following categories: photodegradation studies of polymers; physical and chemical modification of fibers and fabrics; evaluation of textile properties, and development of test methods; serviceability of textile products; synthesis and characterization of UV stabilizers and fungicides; surface modification by electric-field plasma treatments; polymer morphology.

There is a continuing programme connected with the light-induced degradation of fiber-forming polymers, yarns and fabrics. The kinetics and mechanisms of the photolysis of polypropylene and polyethylene terephthalate, for example, are being investigated. Because it is of immense commercial importance as well as of fundamental scientific significance, we are

determining what chemical groups in fibers are absorbing damaging wavelengths from terrestrial sunlight, how this may lead to the breaking of polymer chain bonds, and how to reduce it in order to prolong the useful life of the relevant textile products.

Another aspect of this research is directly related to the Utopian concept of developing laboratory methods of duplicating outdoor weathering, in order to measure and predict durability. Using Xenon-arc and carbon-arc light sources and carefully character-

Increasing magnifications using the scanning electron microscope:
Top=corroded metal. Centre=agglomeration product. Bottom=woven synthetic fabric.

ized optical filters, it has been possible to approach correlation with actinic degradation conditions in the case of polyethylene terephthalate yarns under some conditions. In the case of polyamide fibers (e.g. nylon 6 and 6.6), however, seasonal variations in ultraviolet/total radiation ratios, temperature and humidity cycles, etc. appear to complicate the situation drastically. The complexity and variability of formulations used for man-made fibers is an added difficulty.

Concomitant with the above projects is an investigation of the photochemistry of UV protective compounds, e.g., salicylates, metallocenes, nickel chelates, which protect fibers by light-screening and/or by triplet-state quenching. Some progress has been made in defining criteria of effectiveness and methods of incorporation for these additives in specific film, fiber or fabric samples.

The synthesis and characterization of several series of thiocarbonyl compounds has led to the discovery of a number of effective fungicides. A patent application has been filed to cover the use of thiocarbohydrazones. The object in this work is not only to prolong the usefulness of cellulosic materials (cotton, rayon, wood, paper) but to improve the durability of susceptible plastics, plasticizers, and protective coatings.

Structural studies are in progress, primarily involving the modification of fiber and film surfaces by electrical discharge treatments. In connection with this research and with the preparation of bicomponents and composites, the techniques of electron microscopy and attenuated total reflection IR are used.

Test method development is done on a continuing basis in collaboration with the Canadian Government Specifications Board. In the fibers area, there is an urgent requirement for really meaningful evaluation procedures which have a fundamental relevance; this derives partly from the chemical, physical and mechanical complexity of textile structures. One example (from many that could be given) is our current assessment of rate-of-burning measurements as criteria of fabric flammability, and the potential hazard(s) associated with this property.

Theoretical Studies

Radiationless Transitions

Work on radiationless processes in large molecules has continued. Previous treatments of intersystem crossing in aromatic hydrocarbons have been extended to internal conversions. The Franck-Condon factors derived from emission lifetimes have been related to those observed in emission spectra. Recent efforts are concentrating on treating radiationless transitions as a fundamental aspect of the interaction between matter and radiation.

Spin-orbit Coupling

Spin-orbit coupling matrix elements based on $\sigma\pi$ coupling have been calculated for aromatic hydrocarbons. The results account satisfactorily for the phosphorescence radiative lifetimes. The calculations have also been applied to intersystem crossings, and used to explain the lifetime differences between isomeric partially deuterated naphthalenes.

Lattice Dynamics

Complex thermal expansion data for axial metals have been explained as superpositions of anharmonic, elastic, and electronic contributions. Theories for the normal and superconducting electronic contributions have been studied. A model has been solved for a molecular crystal containing one molecule with a different force constant.

Electronic Transport

Electronic transport in molecular crystals has been studied on a model involving quadratic electron-phonon coupling. Solutions obtained in several perturbation limits cover the wide range of parameters expected in highly anisotropic crystals. The model accounts very satisfactorily for various experimental results on triplet exciton diffusion coefficients and carrier drift mobilities in anthracene. An isotope effect on carrier drift mobilities has been predicted and probably observed. Work is continuing on Hall mobilities and on generalised solutions of the model obtained by many-body techniques.

Many-Body Interactions in Solids

Many-body theoretical methods have been used to develop microscopic theories describing optical properties and excitation spectra of the following systems:

i) Excitation spectrum of interacting polaritons in the infrared region of frequencies of dielectric crystals.
ii) Polariton-phonon interactions in molecular crystals.
iii) Absorption of electromagnetic waves in molecular crystals.
iv) Optical excitation spectrum of interacting polariton waves in molecular crystals.
v) Spin-spin and spin-phonon interactions in the Heisenberg antiferromagnet.
vi) Elementary excitation spectrum of the Heisenberg ferromagnet.

Lattice Dynamics of Molecular Solids

Both the usual Born-Von Karman approach and the method of self-consistent phonons have been used to study the thermodynamic and elastic properties of solid fcc Ne, Ar, Kr, and Xe. Particular emphasis has been placed on the contribution of vibrational anharmonicity, i.e., the phonon-phonon interactions. The crystal excitations, as measured for example by Bril-

louin scattering or the inelastic scattering of neutrons, have been studied theoretically and calculations based upon single models carried out. It is hoped to extend this work to solids with more complicated crystal structures. A calculation of the phonon spectrum and related properties of the quantum solids hcp H_2 and D_2 is also being carried out.

Solid State Studies

Radiation is emitted from the surface of a metal following bombardment with fast electrons. In addition to the transition radiation produced it is probable that surface plasmons contribute to the radiation. A mechanism for the emission of light by plasmons near a surface is being investigated and it is hoped that some progress in a microscopic model for the surface will be made.

The Raman scattering of light by plasmon and optical phonon mixed modes in semiconductor crystals is being investigated.

Electron Scattering

A model for electrons scattering from atoms has been developed. This model is related to the R-matrix approach in nuclear scattering of Wigner and it is hoped to be of use in the study of autoionizing and metastable atoms.

Density Matrix Studies

An investigation of wave functions involving geminals and their relationship to second order density matrices has been completed. A numerical calculation was made to derive such a wave function for the beryllium atom.

An anzats was made for a density matrix describing a diatomic molecule. Numerical calculation in the case of the lithium molecule showed the approximation to be quite accurate.

Some simple results were obtained, relating to the properties of density matrices to bounds upon the energy of a system.

Quantum Chemistry

Recently the concept of integral transform trial functions has been introduced. Work is in progress both on the theoretical generalizations and practical application of the idea. In particular, the following extensions have already been realized.

1) Systematic construction of correlated many-particle trial functions.
2) Natural generalizations of the uniform scaling idea of conventional quantum chemistry.
3) The iteration approach to improve integral transform trial functions and its relation to integral equation formulations.
4) Construction of new types of molecular functions from atomic ones.
5) Systematic generation of novel sets of expansion functions.

Successful practical applications include the construction and numerical testing of new radial functions for two-electron atomic and molecular systems (2- and 3-center molecules). The new integral transform radial orbitals are generated both from Slater and from Gaussian 1s functions. Calculations are in progress on 3- and 4-electron atomic systems, using ideas based on 2) and 5). Excited states of He-like atoms are also under scrutiny.

Work is being initiated in the computational implementation of extensions 1, 3, and 4.

Integral transform trial functions give rise to multidimensional integrals. In this connection several N-dimensional integration schemes are being tested. Some new ideas about alleviating the integration problem are also under development.

Thermochemistry

Thermodynamics of Solutions

A dilatometer suitable for measuring small changes in volume associated with the mixing of liquids has been constructed. This apparatus was used to measure the excess volumes of 11 binary n-alcohol systems at 25°C. Application of the principle of congruence to these results was examined. As in the case of the excess enthalpies studied previously, the excess volumes of binary n-alcohol systems are only approximately congruent. However, the deviations of the enthalpies and volumes from congruence display an interesting parallel behaviour.

The excess enthalpies, volumes, and Gibbs free energies of isopropanol + n-decanol mixtures were determined at 25°C and compared with the results of similar studies of n-propanol + n-decanol mixtures. In both systems, the formation of mixtures apparently involves a net breaking of hydrogen bonds, but the effect is greater in the case of the isopropanol system.

The Flory theory of solutions has been used to correlate results reported previously for the excess enthalpies and excess volumes of a number of aromatic-alicyclic systems.

The heats-of-mixing calorimeter has been modified by the installation of a thermoelectric cooling module. This change makes it possible to study exothermic as well as endothermic mixing processes. The performance of the calorimeter was investigated by measuring the excess enthalpies of the systems benzene + carbon tetrachloride, benzene + cyclohexane, p-dioxane + carbon tetrachloride, benzene + dichloromethane, dichloromethane + p-dioxane, and cyclohexane + n-hexane. The latter system is of particular interest since it is being considered as a standard for checking heats-of-mixing calorimeters. It was investigated in this laboratory as part of an international

co-operative study under the auspices of the Commission of Thermodynamics and Thermochemistry of IUPAC.

Enthalpy and volume changes accompanying the mixing of isomeric xylenes with benzene and with toluene were determined by direct calorimetric and dilatometric measurements. The results were correlated in terms of the theories of Barker and of Flory.

A dynamic-circulation still has been constructed and used to study the vapor-liquid equilibria of benzene + m-xylene mixtures.

Excess enthalpies, volumes, and Gibbs free energies have been measured for the system cyclopentane + carbon tetrachloride at 25°C. A similar study of the system cyclopentane + tetrachloroethylene is in progress.

Surface Energies of Crystals

Summations of Lennard-Jones (6-12) interaction energies were carried out for approximately spherical clusters of face-centred-cubic arrays of rare gas atoms. Clusters containing from 13 to 1337 atoms were investigated. It was found that the apparent specific surface energy increased with increasing size of cluster. For a cluster of 13 atoms, the apparent specific surface energy was about 10% less than that of a {111} face of a large crystal.

Previous calculations of the distortion in the five outermost layers of a {100} face of an alkali halide crystal with NaCl-type structure were extended to incorporate the features of a shell-and-core model, in which the ions were considered to be positive cores surrounded by negatively charged rigid shells. Qualitatively, the distortions estimated with the shell-and-core model have the same features as derived from the earlier calculations, but the new values of the ionic displacements and of the polarization effects are smaller.

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During 1969 the efforts of the Division of Mechanical Engineering were distributed approximately as follows:-

Transportation Technology	46%
Manufacturing Technology	29%
Standards and Standardization	11%
Computer Application Developments	7%
Medical and Surgical Instrumentation	4%
Engineering and Biological Control Systems	3%

Transportation Technology

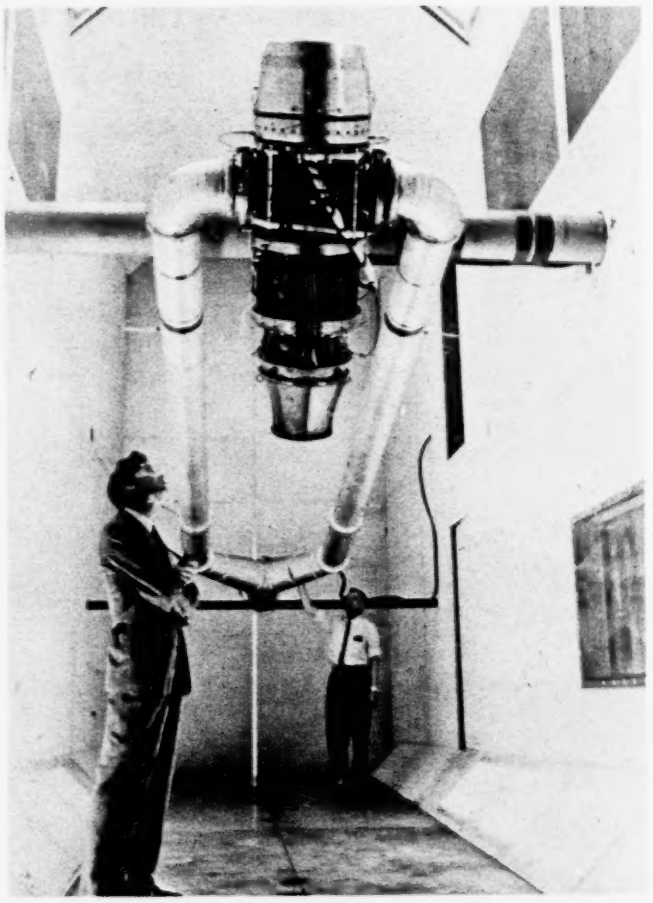
The transportation work has been roughly equally divided among land, sea, and air developments. On the land there has continued a substantial body of activity related to the welding of rails for the Canadian railways, apparatus for preventing the malfunctioning of railway switches in the winter time, and work pertaining to gas turbines and compressors for gas pipelines. There has also been a need to examine various aspects of the introduction of containers into ocean and land shipping, whether by rail or road.

Although the shipbuilding activities of the country have been somewhat quiet during the year, there has been a substantial body of research and development activity pertaining to special purpose ships, marine air cushion vehicles; and there has been in hand a very large project related to the navigational improvements of the St. Lawrence River in both summer and winter conditions.

The air transportation activities of the Mechanical Engineering Division of the National Research Council have naturally been related to the aspects of air transport coming within the field of concern of the Division, namely research and development work and certification pertaining to new engines. The research and novel investigational work has been mostly concentrated on various aspects of engines appropriate to VTOL aircraft.

It is, of course, necessary in an extensive research programme of this sort to be reasonably certain that there will be a market for the eventual application of the VTOL aircraft for commercial air transportation in the late 1970's and beyond, and for this purpose we have accordingly established a close liaison with potential manufacturers and interested Canadian air carriers as well as with various government departments and agencies at the federal, provincial, and municipal level.

As a result of this opportunity to exchange views on various aspects of economics, noise, safety, letdown aids, etc. related to VTOL engineering research programmes, it has been interesting to note the keen attention that is being given to this revolutionary form of air transportation. As a result, there is now in our minds little reason to doubt that VTOL aircraft will be an important series of types in the latter part of this century, when the rapid trend toward increased urbanization in this country coupled with the general population growth, will make it increasingly difficult to set aside property in the centre of urban areas for other types.



Experimental VTOL Power Unit Mounted in 10′ × 20′ Propulsion Wind Tunnel.

Manufacturing Technology

In the manufacturing field, a first activity consists in the application of 2-phase heat transfer pipes to the maintenance of permafrost in various kinds of Arctic construction, and the de-icing of navigational buoys on the East Coast of Canada. A second project, now reaching the exploitation stage by a Canadian company, is the use of high pressure water jets for cutting various kinds of materials, the first one of which is newsprint, which is necessarily cut at very high speeds if paper machines or re-winding machines are not to be hampered in their operation.

A variety of manufacturing processes not yet in general use in Canada are being energetically used and widely publicized in single or two-page newsletters which have themselves given rise to a most enthusiastic response through Canadian industry. Several examples of the new technologies are the generation by grinding of precision case hardened gear teeth, the generation of complicated shapes in a variety of materials by electrochemical machining, and the application of numerical control for much enhanced productivity of machine tools on single articles or small lots. There have already occurred a number of instances in which these various technologies are of valuable consequence to the Canadian industry.

Standards and Standardization

In addition to the calibration of instruments, lubricating oils, fuels and various apparatus for Canadian industry as required by the National Research Council Act, the various laboratories of the Division of Mechanical Engineering have been involved in the certification of the airworthiness of helicopters and various gas turbine engines in conditions of snow and sleet.

Computer Application Developments

In the present circumstances of highly expensive construction of prototype machinery and the expense of arranging complicated experiments even with conventional machinery, the application of computers

to the simulation of projected machinery performance has become very important. In the Mechanical Engineering Division of the National Research Council, typical examples of work pertinent to the investigation of the parallel operation of compressors on gas pipelines, the transients resulting from changes in operation and the corresponding controls; systems analysis of certain control components and the general control features of a new nuclear power station, and of a hydro electric power station (in collaboration with the University of the West Indies); dynamics of high speed railway container cars; and new designs of reciprocating engines.

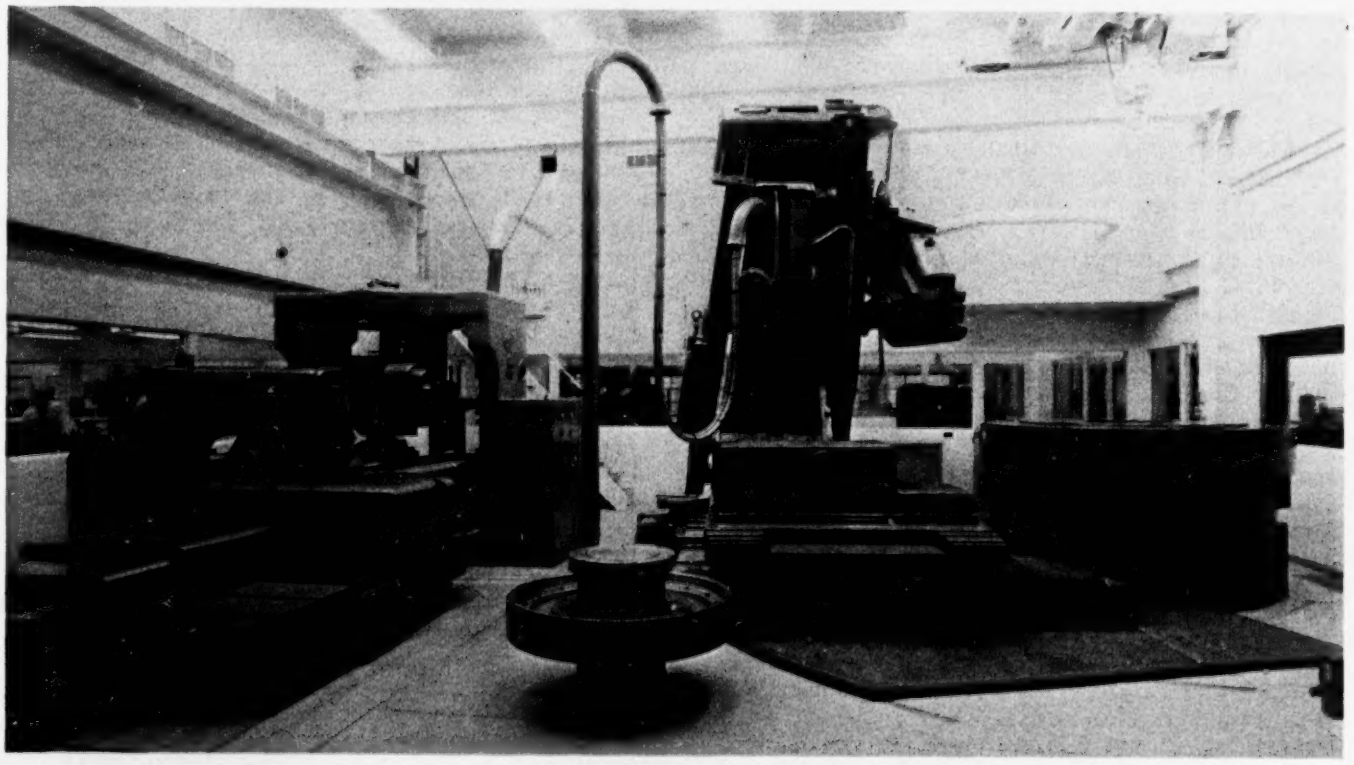
Medical and Surgical Instrumentation

There continues to be a vigorous requirement for new instrumentation for medical and surgical purposes. The work in progress in this line of endeavour ranges on the one hand from the design of prototype instruments for extremely difficult but very important operations on the spinal chord, to, on the other, the final arrangements for production and marketing of a suturing instrument for blood vessels. The first activity is a collaborative one with the Montreal Neurological Institute and Queen's University, and the second one is related to the licensing of a Montreal manufacturing firm.

Engineering and Biological Control Systems

Work continues vigorously in the industrial application of control theory—mechanical, electronic, and fluidic, and the application of control system technique to animate beings. In particular a considerable body of work has now been accomplished in relation to the effects of microwaves on birds, and the possible supply of electrical control impulses to the muscular system of paralyzed people. This latter subject is still at too early a stage to be assessed finally.

Conversely, progressively more detailed investigations are being made of biological control systems as possible models for better and more reliable engineering systems. In particular, the nervous structure of the spinal chord of a cat has been examined at high magnification and in considerable longitudinal detail; and the observations have made evident the extreme reliability attained in this circumstance by the provision of parallel controls and the remarkable decentralization resulting from closed subsidiary loops.



Maag 360 and 90P Gear Grinders in Temperature-Controlled Room of the Manufacturing Technology Centre in the Division of Mechanical Engineering. The Maag 360 is the only equipment of its kind in operation in Canada using the Ferranti precision indexing read-out. Many Canadian firms have been able to make use of these facilities when faced with emergencies in their own operations.

Conclusion

Since it is of course self-evident that this kind of activity needs to be related in a widespread but nevertheless detailed way with the technical and social activities of the country as a whole and with certain corresponding activities in other countries, it has been necessary to evolve a steadily enlarging system of communication.

This system consists in the most general sense of an Advisory Board and is supported by a variety of personal contacts, partly through associate committees and partly in the form of direct liaison with other organizations. In engineering work it is of course also necessary to deal in an enormous amount of quantitative detail. This sort of information is customarily transmitted by short films, by ordinary business letters, by the system of newsletters referred to above, by technical reports, and by papers presented to learned societies.

D. C. MacPhail,
Director.

Publications of the Division of Mechanical Engineering, 1968–70

Much of the work is published as laboratory reports issued by the Division, while some is reported in periodicals. Other reports, not listed herein, include classified projects that may not be freely reported, contractual projects of limited general interest, calibrations, routine analyses, and the testing of proprietary products. The Division also publishes a Quarterly Bulletin jointly with the National Aeronautical Establishment. A list of research reports is available on request. The following have been published during the past two years.

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NATIONAL AERONAUTICAL ESTABLISHMENT

F. R. THURSTON, *Director*

The Advisory Board to the National Aeronautical Establishment is in Process of Formation

Low Speed Aerodynamics

In most of the larger industrialized countries of the world, the aircraft industry owns and operates its own wind tunnels and other major experimental equipment. In Canada the relatively small size of the individual firms has made it of economic advantage to build all the large wind tunnels now available to industry in the laboratories of the National Research Council in Ottawa. As a result, a large proportion of the aerodynamic program is devoted to experimental work, done under direct contract with the aerospace industry, and contributing directly to the design and development of new hardware. Every significant aircraft and rocket designed and developed in Canada during the past 20 years has been partially or wholly supported by wind tunnel experiments at N.R.C.'s National Aeronautical Establishment (NAE).

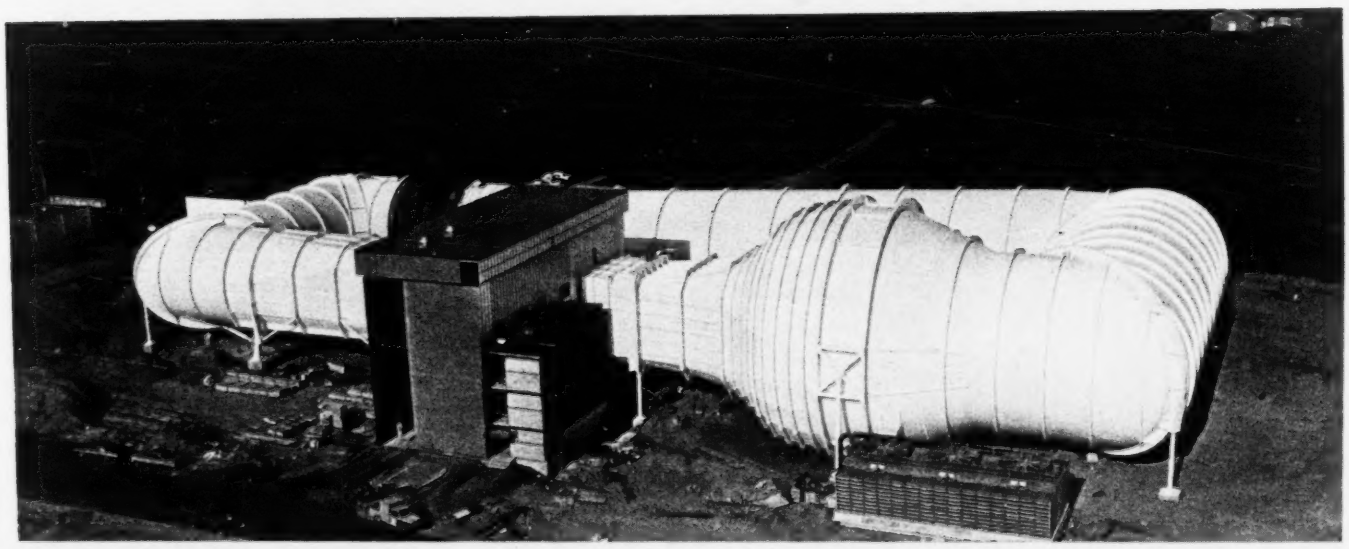
Since about the mid 1950's, the Canadian aircraft industry has made significant advances in the development of vertical or short take-off and landing (V/STOL) aircraft, and as the state of this art has become increasingly competitive and sophisticated, it has been necessary to provide support in a number of areas within the NAE. In 1966 the first contracts were let for the construction of the new 30 ft. low speed tunnel at the Uplands airport site, and this tunnel began its commissioning and calibration runs toward the end of 1969, with the first experimental work scheduled for the Spring of 1970 on an 18-ft. span model of a new Canadian STOL aircraft design.

Other in-house V/STOL research that has been completed within the past two years in the Low Speed Aerodynamics Section includes an experimental investigation of the aerodynamic characteristics of the tilt wing VTOL system, a theoretical analysis of the aircraft configuration parameters leading to minimum energy requirements in slow flight, and a research program aimed at minimizing the effects of wind tunnel walls on the measurement of forces and moments on V/STOL models.

During 1968 and 1969 there has been a significant increase in the number of requests for non-aeronautical wind tunnel work. Much of this has arisen because of the difficulties in designing long-span bridges that will be free of wind-induced oscillations, and approximately 10 different elastically-mounted models of bridge decks have recently been investigated in the 15 ft. vertical wind tunnel under contract with various firms and Government agencies.

Other non-aeronautical wind tunnel investigations have resulted in successful modifications to the structure of a heavy water plant with tall towers, and a microwave antenna array, and have provided useful information on the spectrum of gust-induced loads on tall buildings in a city environment.

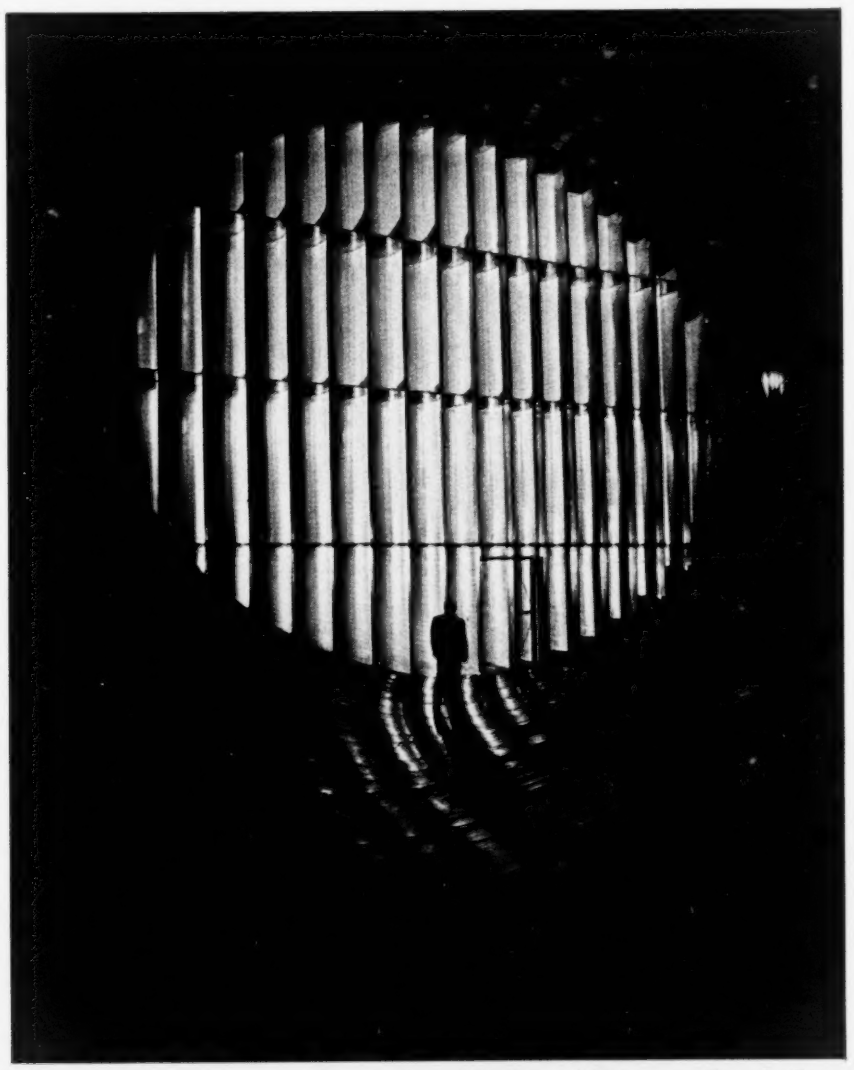
Well-designed aeronautical wind tunnels produce a smooth, uniform air flow in their working section, and do not simulate the large-scale gustiness and shear flow of natural winds at low altitudes. Wind tunnel studies of structural problems such as those just mentioned would be enhanced if a technique were



Final segment being installed on 30 foot wind tunnel.

available for correctly "spoiling" the tunnel flow, and possible future tunnel research in atmospheric pollution would absolutely require such a technique. An investigation aimed at developing an experimental method for doing this was begun about two years ago and its first phase has been concluded. An array of tapered "spires" has been developed, which can be scaled for any wind tunnel; the array reproduces successfully the distribution of mean velocity shear, turbulence level, and the spectral distribution of longitudinal turbulence under neutrally stable, or high-wind conditions in the lower 2000 feet of the atmosphere.

A research program is continuing to demonstrate the feasibility of measuring flow quantities in gases and liquids by means of rugged but sensitive fluidic devices having no moving parts. A fluidic sensor has been patented for the measurement of low velocities and turbulence in air and water, and is being manufactured by a Canadian firm. Patents have been applied for on similar devices for the measurement of higher velocities, turbulence, and fluid density. Further developments, with applications to oceanographic measurements, are being carried out under a NATO grant.



Man standing near one of the series of baffles which carry the air flow around the tunnel's four corners.

Flight Research Section

Flight research is conducted by the NAE to supplement the work of the other aeronautical laboratories in exploring new avenues for aircraft development, to find solutions to their operational problems and to facilitate their application to new functions.

In the first and second of these categories the emphasis in recent years has been placed upon research on VTOL and STOL aircraft handling qualities, and upon research on atmospheric turbulence. Airborne simulators, evolved using helicopters with variable

stability and control characteristics, have provided the means for systematically investigating the effect on handling qualities of the numerous individual parameters involved. The small helicopter at present used for this work is undertaking flight programs to provide new information, essential to designers, on suitable values for these parameters, on limitations due to pilot response and on the probable flight behaviour of projected aircraft. A larger helicopter has been acquired to provide an increased future capability for airborne simulation.

Flight investigations of the properties of turbulence and their effects on aircraft behaviour have continued through the use of two jet aircraft. During the past two years one of these, a T-33 has been used primarily to study the occurrence of turbulence in clear air, particularly in and near jet streams. Measurements made by this aircraft have enabled the magnitude of various terms in the energy equations to be deduced, providing further insight into the mechanisms leading to the generation of turbulence. The other aircraft is an RB57F operated by the USAF. This aircraft has been fitted with an NRC recorder with a memory capability triggered only by atmospheric disturbances above certain critical levels. Over a period of more than a year this recorder has accumulated data on more than 50 disturbances encountered at stratospheric altitudes between 40,000 and 64,000 ft, representing approximately 1.2 per cent of the total flight time spent at these altitudes, which are typical of supersonic transport cruising levels. The instrumented T-33 aircraft has also been used to evaluate the persistence of high intensity vortex wakes behind large aircraft, since these wakes present a hazard to other aircraft and are becoming a significant factor in establishing air traffic separation criteria.

Considerations of flight safety, which initiated the successful development of a crash position indicator for fixed-wing aircraft, led to a program to develop a comparable device for helicopters. A mobile test rig has been built and is in operation for experiments to study the behaviour of lightly loaded objects released in the presence of rotor air flows, and to evaluate possible systems prior to full-scale flight trials.

Flight research relating to aircraft applications has necessitated the continuance of work on airborne magnetic detector systems for ASW and geophysical purposes, and on the behaviour of fluids when dropped in bulk from aircraft for forest fire suppression. The North Star aircraft, used as a flying laboratory for aeromagnetic research, has also been employed recently for the preliminary assessment of infra-red techniques for various survey purposes.

During the past year, a small aircraft has been equipped as a vehicle for a program to develop aircraft spray systems having improved characteristics of uniformity of droplet size distribution. A second T-33 aircraft has also been equipped to participate in hail suppression experiments being conducted in Alberta, just east of the Rocky Mountains. This aircraft is capable of dispensing pyrotechnics containing silver iodide, while flying above building cumulus towers. The pyrotechnics are launched vertically downwards and are fused to generate silver iodide at a maximum rate immediately above the freezing level.

High Speed Aerodynamics

The High Speed Aerodynamics Section is centred around the NAE 5-foot trisonic blowdown wind tunnel, but also makes limited use of a 5-inch supersonic and a 12-inch hypersonic gun tunnel for basic research studies. During the review period the large trisonic wind tunnel was used for a variety of aerodynamic investigations for the aerospace industry, defense services and for internal research work. Typical of the tests made for industry were longitudinal stability measurements of flexible rocket vehicle models; a succession of increasingly complex flutter investigations of models of a large tri-jet aircraft (airbus); static lateral and longitudinal stability and hinge moment measurements on rigid and flexible models of a strike fighter aircraft, and trajectory studies of small solid fueled rockets launched from these same wind tunnel models. Most of these investigations have utilised the high Reynolds number capabilities of the 5-foot wind tunnel and have been carried out in the high subsonic and transonic speed ranges.

Recently the high Reynolds number transonic performance has been enhanced by the provision of insertable wall sections which reduce the test section area to 5 feet by 1¼ feet, but enable the wind tunnel to be operated at higher pressures. This unique two-dimensional test facility, which has attracted widespread interest, has been commissioned, calibrated and used by several aerospace companies to develop transonic wing sections. Investigations in this facility are supported by internal research work aimed at the development of theoretical methods of aerofoil design for supercritical transonic conditions. Cooperative experimental and theoretical research programs with the Courant Institute of Mathematical Sciences, New York University and the Convair Division of General Dynamics on "shockless" high lift transonic aerofoils including the effect of jet flap blowing, are also in progress. The research work of the Section has been concerned with three-dimensional boundary layers and flow separation, the computation of three-dimensional inviscid and interacting flow fields, and the design of supercritical transonic aerofoils, mentioned above.

Fundamental studies have been made of the three-dimensional laminar boundary layer, with and without suction and on cones, and also the two-dimensional turbulent boundary layer using finite difference techniques with the turbulent shear stress described by

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various mixing length models. Measurements have been made of the laminar and turbulent boundary layer growth, separation and vortex structure about lifting circular cones in subsonic, supersonic and hypersonic flows.

Other experimental research programs involving three-dimensional viscous flows have included: Magnus force measurements on mortars spinning at high rotational speeds, the separation on long slender ogive-cylinder models and the resulting side forces, the turbulent boundary layer development and separation on a slender ellipsoid of revolution at incidence to a subsonic stream, an investigation of fuselage boundary layer separation caused by side mounted supersonic intakes and a related study of separation caused by the glancing interaction of an oblique shock wave system.

A powerful numerical method for calculation of the complete inviscid flow field about general conical bodies at incidence to a supersonic stream, has been developed and extensive tables of results for the lifting circular cone have been published (AGARDograph 137). These tables will undoubtedly become a standard reference for workers in the field. The method is also being used to study the effect of specific heat ratio on the flow field about hypersonic lifting bodies.

The second three-dimensional numerical flow field study that has been made, computes the inviscid-viscid interacting hypersonic flow inside converging ducts of circular cross-section. This study follows early work based on the imploding shock analogy and a modified shock layer theory for such intake flows. Experiments in support of this theoretical work have been made in the hypersonic gun tunnel.

Structures and Materials

Environment

The study and analysis of the flight operations environment is a pursuit that demands, more than any other, the international coordination and exchange of information. Through the Advisory Group for Aerospace Research and Development, Canada has participated in a number of programs, two of the more important current ones being: (1) the compilation of a reference source of aircraft response to flight turbulence based on the pooled data of the NATO countries, and (2) the analysis and ultimate preparation of data sheets covering high intensity noise fields and structural responses which may be involved in the phenomenon of acoustic fatigue. The Canadian share of funding to defray AGARD's costs of carrying out these coordinated efforts, is contributed jointly by the DND, DOT and NAE, with NAE carrying the technical responsibility.

During the past few months, the measurement of flight load statistics has emphasized the exposure of light aircraft such as are used in survey, pipeline overflying, and agricultural or special commercial operations. Reports have been prepared and will continue to be prepared and made available as data are received and processed. The increased use of flight load statistics recorders and fatigue spectrum monitors has raised the need for improvements to the technique for the input-output calibration of low-frequency large-amplitude acceleration indicators and counters. The development of an electro-hydraulic system is currently in hand and is expected to be in operation in time to handle the new generation of DND operational V-G-H recorders. In this connection, NAE has carried out advanced computer programming for analysis of the Leigh Instruments V-G-H recorder, and will work with DND in processing the output from this new operational aid for the CF-5 aircraft.

The results of work in the near field sound pressures of a choked jet during what is termed the screech cycle, has evoked very great interest from operators and manufacturers. The object of this work was to establish a possible correlation of pressure fluctuation over a structure in the near field noise. Instrumentation was developed to measure instantaneous pressures near to a two-inch diameter screeching jet, as an extension and complement of our previous root-mean-square field pressure measurements. Flow visualization of the sound field oscillations were projected onto a two square feet diameter screen, with the aid of an improved Schlieren system, and a film of the stroboscopic motion has been released for technical viewers.

The flight impact simulator has been used to document a number of study sequences of bird impacts against aircraft windshield and airframe components. Now calibrated up to 420 knots, and controllable with $\pm 2\frac{1}{2}\%$, impact records correlating velocity, temperature, strain, and fracture modes are obtained with high speed photography and chart recorders. Current evaluations of a DND trainer aircraft will also see the completion of a controlled enclosure capable of handling steady state temperatures from $-65°F$ to $+150°F$.

Materials

Investigations and studies which have been pursued in the materials laboratory are associated with three primary objectives: the protection of high temperature metals (refractory and superalloys), the development of composite materials technology, and the analysis of material failures in aircraft operation and industrial processes.

The measurement of lattice diffusion coefficients for the Nb-Ti system was continued with studies of the diffusion of ^{44}Ti into niobium single crystals in the temperature range 994–1492°C. Penetration analyses were made, using an anodizing-stripping sectioning technique. Non-linear penetration profiles were observed, composed of two or three segments depending upon the presence or absence of near-surface effects.

The stripping sectioning technique employed allows a clear observation of those effects, and a discrimination to be made between diffusion along defects and true lattice diffusion.

The first part of a two-part report on the formation and oxidation resistance of a Cr-Ti-Si diffusion coating for niobium alloy B66, was completed. In conjunction with this work, analytical techniques were extended for identifying intermetallic compounds in coating systems. Preliminary experiments were completed to test the influence of Na_2SO_4 on the oxidation resistance of the Cr-Ti-Si coatings in the range 1100°C to 1300°C. It was observed that the presence of condensed sodium sulphate on the surface of the coated B66 specimens, promoted rapid oxidation of the coating, together with penetration of the coating by interstitials. A simulation of the true sulphur-containing environment of aircraft powerplants will need to be made before an assessment of the operational implications of this coating performance can be finally assessed.

In a report on the oxidation resistance of aluminide-coated 713C and IN100 superalloys, it is indicated that the best resistance was provided by a sulphidation-resistant Al-Cr diffusion coating. Cycled between 150°F and 2000°F, the coated IN100 alloys were characterized by the development of localized oxide growths. These defects were observed to form where primary γ^1 phase particles extended from the substrate through the coating to the outer surface.

The interest of Canadian researchers in the use and development of the new ultra high performance composites, has shown up a critical lack of the prerequisite experience which foreign technologies have mastered over a period of time, in accomplishing high quality composites in less sophisticated materials. Work in the N.A.E. materials laboratory is aimed at showing the way to reliable composite structures through complementary studies on matrices, reinforcement phase, processing steps, design and fabrication techniques. Studies have involved matrix materials made from various combinations of epoxide family resins with cross-linking compounds and polymerisation initiators. Observations which have been reported include: qolymerisation of epoxide resins with phthalic anhydrides by preactivation of the resin; preparation of ammine adducts and their polymerisation with epoxide resins; a method for determining exothermic temperatures of reacting compositions, and the determination of physical properties.

Attention has been focussed on the development and application of diffraction methods of residual stress analysis. Researchers have reported anomalies between strain gauge and X-ray indications. An examination of the residual stress distributions in experimental cold rolled sheet material was therefore carried out to verify reported findings, and to establish an appreciation of the meaning and usefulness of residual stress data obtained by these methods. A 7030 brass was selected for the experiments because of its low stacking fault energy. Measurements indicated that the surface residual stresses produced were tensile, balanced by internal compressive stresses. Only at high deformations were there any indications that this distribution could reverse. In this work, the large magnitude of the micro-stresses led to such line broadening and diffused diffraction patterns, that an important degree of accuracy is lost. A point of considerable interest which came to light, and contrary to the expectation that stacking faults would become so extensive at high deformations as to mask other effects, was that no stacking faults were observed in specimens plastically deformed in excess of 50%. Clearly, a further investigation of this finding must be carried out.

Fatigue and Fracture

In the very heavy demand for fractographic analysis of metal failures, a number of opportunities have been afforded to test and improve techniques for the examination and interpretation of fracture surfaces. Investigation of service fatigue in the main spar flange of the CL41 aircraft, for example, has enabled the direct fractographic comparison of a service-produced crack with its laboratory equivalent produced under full-scale simulated test conditions. Correlation of the load program crack progression lines, the individual striations, and the relative striation spacings observed in the fracture surfaces, are being analysed to improve post mortem interpretation techniques. In a continuation of this particular project a modification introduced by the manufacturer is undergoing simulated flight load spectrum tests, with the expectation of achieving an acceptable service life rating. Also in hand is a complementary study of crack propagation rates and fracture topography of ASTM—A325 high strength steel bolts, which are being failed under program loads featuring predetermined mean load level and load amplitude relations.

Following an observation of the rather poor fatigue performance of a welded 18(250) maraging steel component, an investigation of fatigue in simple butt-welded plate samples prepared by a qualified manufacturer and by the NRC Experimental Workshops, was carried out. The results for as-received rolled and aged plate subjected to pulsating tension, indicated a fatigue limit of about 44±36 ksi. For the butt-welds, a fatigue limit of only 18.7±15.3 ksi was found. While removal of the weld bead by grinding appears to increase the average life, particularly when grinding is carried out after aging, the best performance achieved in this regard was still inferior to that reported by other investigators for specimens taken from bar stock.

Initial results have been obtained from interferometric measurements of strains in the thickness direction of symmetrical edge notched 2024-T3 and 7075-T6 aluminum alloy sheet specimens, loaded in tension. Intended to provide advisory information about the accuracy of Neuber's relations for plastic

stress intensity factors, a few preliminary measurements have been made using the method of G. V. Oppel, et al., to complement grid technique measurements. By this method, interference fringe patterns produced by means of a light beam, which is incident upon a partial mirror placed against the surface of the specimen, permit mean thickness-direction strains to be estimated. The results obtained suggest that certain deficiencies exist in existing grid strain measurements; a fuller program of observations is being made to obtain more precise and detailed information in this regard.

Mechanics

The very substantial participation of our mechanics group in the development and application of finite element techniques in shell analysis was continued, and a number of important contributions were published in leading journals. Following convergence studies of eigenvalue solutions, in which the adequacy of the group's conforming element was verified, attention has been turned to the application of these advanced elements to the prediction of vibration and dynamic aeroelastic responses.

In one line of study a curved triangular element has been developed and applied to the vibration analysis of a shallow spherical cap, to a thickness-tapered high camber fan blade, and to a dish antenna model. A coordinate transformation is now being sought for the stiffness characteristics of this element that will enable an extension of its application to the analysis of deep shells.

The potential of the finite element concept for solving aircraft flutter problems which are amenable to two-dimensional aerodynamic theory, was demonstrated using as examples a square simply-supported panel in supersonic flow, and certain cantilever delta wings for which experimental flutter results were available. Work is now underway to formulate the full three-dimensional unsteady supersonic aerodynamic theory in a form for finite element applications.

Two computer programs relating to studies in automobile safety are nearing completion. The first of these is a model of the flow of traffic on a two-lane rural highway; the second models the vehicle-safety barrier impact and arrest process. Initial computer results for the simulated barrier arrest using average vehicle properties, reproduce field experimental observations acceptably well. Apparatus is under construction for measuring the experimental vehicle properties accurately; based on this the computer program will be checked carefully against the on-board measurements, and photogrammatic data acquired in field trials for a number of key situations involving vehicle speed, impact angle and barrier properties.

In a precedent-setting move by Mr. Justice Edson Haines during his hearing of a highly technically-oriented civil action, a member of the automobile safety study group assisted His Lordship on the Bench as technical adviser.

Miscellaneous Involvements

Services rendered to the industrial and scientific community through the special abilities of the staff and laboratory facilities represented a substantial level of laboratory effort. Analysis of the Tutor Aircraft fatigue exposure prior to setting up a laboratory fatigue test involved: study of the flight load spectrum and synthesis of an equivalent spectrum block simulation, metallurgical and residual stress analysis of critical parts, and measurement and analysis of stress and deflection influence lines for a wing unit-loading grid. Assistance in accident and materials failure analyses saw several dozen electron fractographic examinations carried out, including requests from the Department of National Defence, Department of Transport, Commercial airlines and automobile road accident investigators. Special lecture and technical instruction course material included such topics as finite element analysis, jet efflux noise, electron fractographic techniques, principles of strain gauge circuits and strain measuring instruments, statistics of secondary load reference standards evaluation, and blast pressures in the NAE pneumatic gun muzzle efflux, etc.

Unsteady Aerodynamics

Unsteady supersonic and hypersonic flows were studied both analytically and experimentally, and including inviscid as well as viscous flow phenomena.

Inviscid flow over wedges performing low-frequency oscillation with an amplitude of the order of the wedge semi-angle has been determined, introducing an unsteady perturbation of the quasi-steady flow around a wedge in an instantaneous deflected attitude. This method was used for slender wedges, using the hypersonic small disturbance theory, and for arbitrary wedges (but subject to the condition that the shock wave remains attached) using more complete basic flow equations and shock wave relations. Simple closed form expressions for unsteady surface pressure on slender wedges and cones have also been derived.

McIntosh's work on wedges was extended to slightly curved aerofoils, by introducing a parabolic perturbation of the wedge shape. The resulting infinite series was reduced to simple closed-form expressions for reduced frequencies much smaller than unity.

A method similar to that introduced by Brong for circular cones is being developed for cones of general cross-section. An available zero-incidence steady flow field about a body is perturbed with respect to angle of incidence and pitching velocity and their time derivatives, which limits the applicability of the method to small values of these parameters.

The effect of boundary layer on the surface pres-

sure on oscillating bodies can be calculated by the new important method of dynamic viscous pressure interactions. This method, of which simplified special cases were published earlier, is based on the consideration of the boundary layer displacement surface and its motion relative to the body surface, which defines an effective change in the motion of the body caused by viscous effects. The method is quite general, since by using a suitably defined effective boundary layer displacement thickness, the method also lends itself to future applications involving mass addition and viscous and ablative phase shift effects in the boundary layer.

In support of the above analytical work a large volume of experimental work has been conducted in the 30 inch supersonic air wind tunnel and the 11 inch hypersonic helium wind tunnel. This work comprises measurements of static and dynamic stability derivatives on elastically supported wedges and cones (including elliptic cones) and on free-flying cones, measurements of surface pressures and hot-wire and pitot traverses on oscillating flat plates and wings, flow field visualization studies using glow discharge technique and high speed camera, and even attempts to study local effects of mass addition into the boundary layer, using low-melting-point sublimators.

Several interesting experimental techniques have been developed, including a new method for remote optical determination of oscillation amplitude, a new apparatus for dynamic stability experiments, and a glow discharge technique for flow visualization. Some aerodynamic characteristics of models in steady flows have also been investigated, such as the relative effectiveness of various square and conical flare arrangements on slender cone-cylinders (of interest for Black Brant work).

In addition, two non-aerodynamic projects were carried out. One involved a development of a new method for the measurement of atomic oxygen and nitrogen in the upper atmosphere, and the other an assessment of the radiation hazards which may be encountered by the passengers and crew on the supersonic transport aircraft (SST).

It was found that for the passengers, the risk of radiation effects in SST could probably be maintained at a comparable level to that of current high-performance, subsonic jets. Under normal scheduling, the crew might accumulate a yearly dose above the recommended general public rating, but well within the limits set for radiation workers. With appropriate scheduling to restrict duty time on polar routes to 200–300 hr/yr, the exposure dose could probably be controlled sufficiently to conform to the recommended general public rating.

Publications of the National Aeronautical Establishment, 1968–70

Much of the work is published as laboratory reports issued by the Establishment, while some is reported in periodicals. Other reports, not listed herein, include classified projects that may not be freely reported, contractual projects of limited general interest, calibrations, routine analyses, and the testing of proprietary products. The Establishment also publishes a Quarterly Bulletin jointly with the Division of Mechanical Engineering. A list of research reports is available on request. The following have been published during the past two years.

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The basic objective of this Laboratory is to study the influence of genetics and environment on the growth and production of micro-organisms, plant cells and higher plants, and the control of these factors to develop new products and improve the quality and yield of present products. While the Laboratory is organized by sections on the physiology and biochemistry of fungi and bacteria, chemistry of natural products, plant biochemistry and process development, a voluntary interdisciplinary approach has been applied to research problems. The cooperation of other Government departments, industry and applied science faculties of universities has been sought where expertise was not available in the Laboratory and particularly on projects of a more applied nature.

Research on plant cell cultures has been expanded to study protoplast formation, cell fusion, embryogenesis, morphogenesis and continuous and phased cell growth. The analyses of terpenes by gas liquid chromatography, and of cell wall polysaccharides by nuclear magnetic resonance spectroscopy has led to notable advances in chemotaxonomy of conifers and yeasts respectively. Research on proteins has been extended to studies on nitrogen fixation, protein components of rapeseed and the potential of field peas as a high protein agricultural product. A more detailed account of the work of the Laboratory by sections follows.

Physiology and Biochemistry of Fungi

Culture Collections

Over 2500 isolates of a wide range of fungi continue to provide a ready source of organisms for experimental work throughout the laboratory.

Fundamental Studies

Continuing studies on metabolism, cell membrane integrity and reproduction of *Pythium* root rots have shown that the presence of cholesterol decreases leakage of nitrogenous components from the cell but increases carbohydrate loss. Polyene antibiotics, ineffective against these fungi which normally contain no sterol, cause increased leakage of cellular components from sterol-fed cells. High local concentra-

Discovery of a sterol requirement for sexual reproduction in certain root-rot fungi (foreground) is leading to better understanding of host-parasite relations and disease control in economic crops, and to a measure of control of structure and function of cell organelles (background).

tions of polyenes may induce oospore formation in the absence of sterol. With certain supposedly heterothallic *Pythiums*, one but not the other of compatible pairs produces oospores in the presence of sterol. Fine structure studies have revealed differences between sterol fed and normal hyphae as well as new features of unit membrane substructure. Electron microscope studies of ultrastructure of fungi have been extended to studies of cells of tissue cultures of higher plants. Various stages in the life cycle of a storage rot of yams have been elucidated leading to more effective control.

Metabolic Products of Selected Fungi

The structures of monochaetin from *Monochaetia compta* and cephalochromin from *Nectria irridescens* have been elucidated. Considerably greater yields of the macrocyclic lactone zearalenone have been obtained than those claimed in the literature, while a strain of *Aspergillus* is yielding over 2.5 g of the antibiotic terrein per litre; *Valsa friesii* is yielding over 1 g metacresol per litre, making possible the production of labelled metacresol for use in studies on the biosynthesis of the antibiotic patulin.

Metabolic Studies

The degradation of flavonoid compounds by microorganisms is studied to gain information on the biological activity of these compounds. Work continues on the biosynthesis of certain metabolic products of fungi from appropriate amino acids. Biosynthesis of the antibiotic valinomycin has been further investigated and a simple production method has been developed. Studies on the effect of various amino acids on biosynthesis of *Aspergillus* species have led to the discovery, isolation, and identification of new analogs of the antibiotic, aspergillic acid. Biosynthetic studies on the complex diketopiperazine, echinulin, have shown that it is derived from a simpler diketopiperazine, cyclo-L-alanyl-L-tryptophyl. Further biosynthetic studies on complex diketopiperazines (mycelianamide, sporidesmin) are planned.

The two asymmetric centres in echinulin have been shown to be *L-L* by comparing the optical rotatory dispersion (ORD) of echinulin, its hexahydro-derivative and the four cyclo-alanyl-tryptophyls. These observations support the biosynthetic studies.

Further studies on the ORD of cyclic dipeptides have been undertaken as a result of the echinulin work, and are nearing completion. The structure of the metabolite monochaetin has been partially determined and it is hoped to establish the absolute stereochemistry. The possibility that this compound would make a suitable biosynthetic study using C^{13} NMR is being investigated. Biosynthetic studies on chrysophanol, pachybasin, and emodin, metabolites of *Trichoderma viride*, are also being contemplated and an investigation of the pigments produced by *Chrysosporium* is in the preliminary stages.

Physiology and Biochemistry of Bacteria

This Section is primarily interested in the catabolism of aromatic and heterocyclic compounds related to plant wastes and pesticides, in symbiotic and asymbiotic nitrogen fixation and in enzymes that hydrolyze components of cell walls.

Culture Collection

A collection of bacteria and yeasts (1000) is maintained as a service for members of the laboratory, and other institutions. These organisms are stored as dried cultures in sealed ampules. A list of cultures maintained in institutions in Canada has been prepared with the aid of a computer. This system was developed at the request of the Associate Committee on Culture Collections and Taxonomy for the gathering, storage, and selective retrieval of information on cultures maintained in culture collections.

Metabolism of Aromatic Compounds

The catabolism of flavonoids is being investigated by both aerobic and anaerobic microorganisms. *Aspergillus flavus*, an aerobe, produces inducible extracellular enzymes that degrade rutin to rutinose, carbon monoxide, phloroglucinol carboxylic acid and protocatechuic acid. A glycosidase removes the sugar from rutin and a dioxygenase cleaves the heterocyclic ring to yield carbon monoxide and 2-protocatechuoyl phloroglucinol carboxylic acid (a depside).

The dioxygenase normally exists as a dimer with a molecular weight of 130,000 and containing 2 moles of copper. The enzyme binds two moles of substrate and adds two atoms of oxygen-18 to the heterocyclic ring, yielding the depside with a free carboxyl group containing oxygen-18 and an ester carbonyl containing oxygen-18. Both the carbon and oxygen of the carbon monoxide are derived from carbon-3 of the heterocyclic ring. In contrast, a *Butyrivibrio* sp., (an anaerobe isolated from rumen fluid obtained from a steer), catabolizes rutin anaerobically to yield phloroglucinol, carbon dioxide, and 3,4 dihydroxy phenyl acetic acid. The enzymes that catalyze these changes are intercellular. This pathway appears to be similar to that reported in animals.

Three aerobic bacterial isolates have been isolated that degrade cyclohexanecarboxylic acid by different pathways. Two of the pathways involve aromatization before cleavage of the ring, with two different intermediates, p-hydroxybenzoic acid and benzoic acid. The third pathway is probably similar to the oxidation of fatty acids.

An organism was found which degrades salicylic acid by conversion to gentisic acid, rather than to catechol. A new pathway for the metabolism of p-hydroxyphenylacetic acid has been found in two organisms. This pathway involves an oxidative shift in position of the side chain, and results in the formation of homogentisic acid.

The microbial degradation of the fluorophenylacetic and fluorobenzoic acids is being studied using an organism isolated with p-fluorophenylacetic acid as sole carbon source. The corresponding chloro compounds are not metabolized by this organism. During growth of the organism on p-fluorophenylacetic acid 3-fluoro-3 hexenedioic acid (trans), L-fluorosuccinic acid and 3-fluoro-3-hydroxyphenylacetic acid have been isolated from the medium.

Nitrogen Fixation

A novel assay developed for determining nitrogenase, the enzyme that converts atmospheric nitrogen to ammonia, is being applied to the study of symbiotic and asymbiotic nitrogen fixation. Nitrogenase reduces acetylene to ethylene, and the determination of ethylene in the effluent gas gives a continuous measure of nitrogenase activity. The procedure has been adapted to determining the activity of nitrogenase in blue green algae and in anaerobic or aerobic bacteria.

The nitrogen fixing bacterium *Azotobacter vinlandii* has been grown in a synchronized culture. Synthesis of the enzyme, nitrogenase, is complete in the first third of the cell cycle. Nitrogen containing compounds affect the enzyme in several ways.

Hydrolytic Enzymes

Purified glycosidases have been prepared from lytic microorganisms (*Basidiomycetes, Streptomycetes* and *Arthrobacters*). Following characterization, these specific enzymes become useful microanalytical tools, e.g., a basidiomycete laminaranase has been isolated that attacks only laminaran ($\beta(1\rightarrow3)$glucan) from the non-reducing end. It also attacks laminaran that contains $\beta(1\rightarrow6)$glucose substituents but will not attack other substituted laminarans or polysaccharides. It acts with anomeric inversion yielding α-glucose, attacks the C_1-O bridge and tends to unzipper individual molecules (multiple attack) as opposed to acting in a random manner. The purified glycosidases (cellulase, pectinases, laminaranases) have been used to prepare protoplasts from fungal and plant species. The protoplasts may be used for the mild preparation of cell organelles by gently lysing them, and potentially may also be used for somatic cell fusion of plants for studies of hybridization and nuclear/cytoplasmic relationships.

Plant Biochemistry

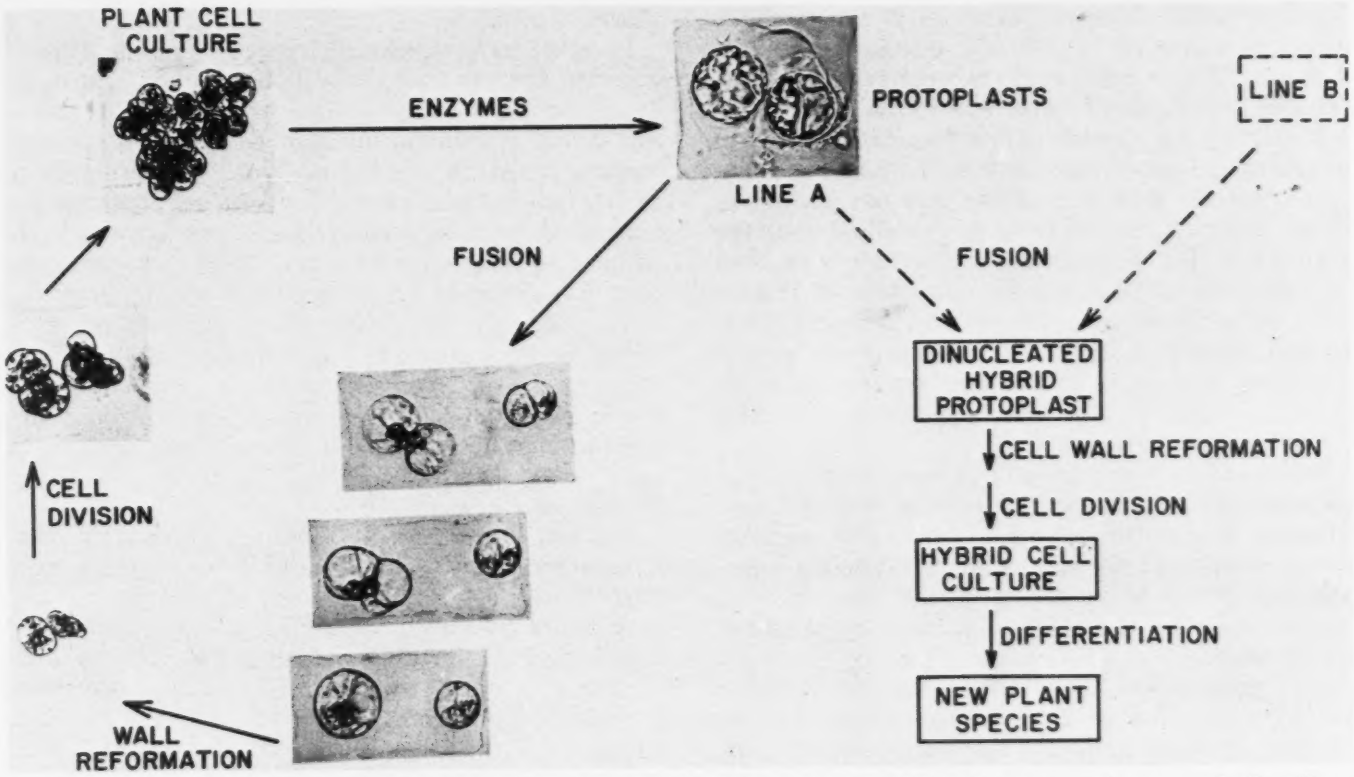
The establishment and maintenance of new plant cell cultures is continuing. Together with these studies the effect of nutrients, growth regulating substances, and other environmental factors are being examined. Investigations have been initiated into the possibility of using cultured plant cells for hybridization studies as well as the regeneration of plants from these cells. Biosynthetic studies of glucosinolates (thioglucosides) and aromatic ring oxygen compounds in higher plants and in plant cell cultures are being pursued.

Plant Cell Cultures

Plant cells are being cultured successfully on a simple medium made up of mineral salts, sucrose, and growth promoting compound(s). A more detailed study of nutritional conditions showed that they can be grown on inorganic nitrogen and do not require amino acids or any other forms of organic nitrogen. In depth studies have shown the influence of the nitrate and ammonium ions on cell growth and nitrogen assimilating enzymes. Soybean culture cells require ammonium in addition to nitrate for growth and further investigation indicated that the cells were deficient in nitrate reductase. Wheat cells grew well on nitrate and did not require ammonium.

To date the following plants have been successfully cultured as plant cell suspensions: 1) Cereals and grasses, e.g., barley, corn, rye, rice, wheat and brome grass; 2) Crop plants, e.g., rape, mung bean, flax, soybean, potato, buckwheat, sweet clover, parsnip, peas, beans and others; 3) Miscellaneous plants, e.g., garden nasturtium, rose, mint *Vicia villosa, V. crassa, Crepis,* and others.

Plant cell cultures produced a variety of secondary metabolites. Coumarins and alkaloids accumulated in cell cultures of *Ruta* and the yields were not affected



The circuit on the left exhibits tetraploidization by fusion of protoplasts following enzymatic removal of walls from somatic cells. Researchers at the Prairie Regional Laboratory are now investigating the use of the pathway on the right to produce new plant types from species which cannot be hybridized by the conventional sexual means.

by growth regulators. *Haplopappus* cell cultures produced anthocyanin pigments and the yield of these could be increased by growth regulators. Plant cell cultures also produced ethylene and the amounts varied with the plant species.

Plant cell cultures are being used in an attempt to hybridize species or genera. After cell wall removal using degradative enzymes, fusion of like protoplasts readily occurred and some fusion of free-floating protoplasts also occurred. The free protoplasts are able to regenerate walls and some of the resulting cells undergo division. Attempts to fuse unlike protoplasts into a viable unit have not yet been successful.

Embryogenesis and morphogenesis of cultured cells is being studied so that hybrid cell cultures, when available, may be used to produce intact plants and thus establish new plant species. Treatment of cell cultures with growth regulators induced morphogenesis, resulting in root formation of wheat and sweet clover cells. Embryogenesis was achieved in cultured cells of carrot and brome grass. The carrot embryos developed into normal plants while the brome embryos produced albino plants.

Apparatus (phytostat) for the continuous culture of plant cells has been developed and other systems are now being tested for use in synchronization of plant cell cultures. Such cultures are essential for furthering the investigation of processes associated with the cell cycle and with cell aging or differentiation.

Biosynthesis of Glucosinolates

The biosynthetic sequence for glucosinolates has been extended beyond the amino acid stage. The following sequence now appears to be firmly established in *Tropaeolum majus* L.; phenylalanine–(1)→ N-hydroxyphenylalanine–(2)→ phenylacetaldoxime–(3)→ phenylacetothiohydroximate–(4)→ desulfobenzylglucosinolate–(5)→benzylglucosinolate. Analogous reaction sequences have been verified in studies on the biosynthesis of other glucosinolates. Cell-free preparations of enzymes have shown the presence of (2) and (4). Recent studies have demonstrated that there is an interconversion of closely related glucosinolates, e.g., 3-methylsulfinylpropylglucosinolate to 3-methylthiopropylglucosinolate and then to allylglucosinolate and of 2-phenylethylglucosinolate to 2-hydroxy-2-phenylethylglucosinolate. Along with these studies several analytical procedures have been developed which allow the investigation of plants having only small amounts of glucosinolates.

Biosynthesis of Aromatic Ring Oxygen Compounds

Furanocoumarins are known to induce skin photosensitization in mammals. They also inhibit cell division and are highly toxic to fish and mollusks. Their biosynthesis was studied using plants from a number of families. In all species a pathway proceeding from 7-hydroxycoumarin through isopentyl-substituted intermediates to psoralen and angelicin was followed. These parent furanocoumarins were further hydroxy-

lated and alkylated in most species. The formation of furanochromones, furanoquinoline alkaloids and similar compounds appears to take place in an analogous way.

Chlorogenic acid comprises 4–8% of the weight of roasted coffee and 10–15% of instant coffee powders. It is also a major constituent of tobacco and some foodstuffs. Tracer experiments showed it was rapidly formed in leaves from p-coumarate or caffeate by direct esterification with quinic acid.

CHEMISTRY OF NATURAL PRODUCTS

Fats and Oils

Structure and Biosynthesis of Glycolipids

Fermentation studies with *Torulopsis bombicola* have continued: 14 and 15 carbon fatty acids are converted to ω and ω-1 hydroxy acids of the same chain length and of chain lengths extended by two carbon atoms. Lactonic and acid sophorosides produced from octadecane have the structures: 17-L-[(2′-*O*-β-D-glucopyranosyl-β-D-glucopyranosyl)oxy]-octadecanoic acid 1,4″ lactone 6′,6″-diacetate and 17-L-[(2′-*O*-β-D-glucopyranosyl-β-D-glucopyranosyl) oxy]-octadecanoic acid 6′,6″ diacetate. A method of locating acyl groups in partially acylated glucosides by nuclear magnetic resonance spectroscopy has been worked out and used to show that the acyl galactosyl diglyceride from spinach leaves is 1′,2′-di-*O*-acyl-3′-O-(6-O-acyl-β-D-galactopyranosyl)-sn-glycerol.

The mechanism of hydroxylation of long chain compounds by *T. bombicola* has been studied. The oxygen atom introduced on hydroxylation comes from molecular oxygen and not from water. Use of appropriate deuterated substrates has shown that a 17-L-hydroxy acid is produced by displacement of an L-hydrogen atom (retention of configuration). A cell-free system which converts oleic acid to 17-hydroxyoleic acid has been obtained. The system is apparently a mixed function oxidase, since it requires O_2 and NADPH.

Composition of Natural Waxes

Few natural waxes have been completely analyzed by reliable methods; beeswax has been examined because its hydroxy acids are very similar to those produced by *T. bombicola*. Wheat leaf waxes are being investigated as the wax may influence water retention, wetting by herbicides, etc.

Beeswax has been separated into mono-, di-, and triesters, hydroxy esters and acid esters. Seven hydroxy acids (ω-1 and ω-2) with 16–24 carbon atoms and 4 diols with 24–30 carbons have been isolated and completely characterized.

Leaf wax of Little Club wheat is composed of: hydrocarbons (8–15%); esters (20–26%), alcohols (25–42%); acids (2%), hentriacontane-14,16-dione (6–10%); 8- and 9-hydroxyhentriacontane-14,16-diones (9–16%) and unidentified material (9–12%). The esters are mainly octaconsanol esters of C_{14} to C_{32} fatty acids but esters of *trans*-2-tetracosenoic and *trans*-2-docosenoic acids also occur. The free alcohols are almost entirely octacosanol.

Biosynthesis of Fatty Acids in Plants

Fatty acid metabolism in developing flaxseeds was studied by incubating whole seeds, embryos and endosperms in buffered solutions of acetate-1-^{14}C, malonate-2-^{14}C and $^{14}CO_2$. Incorporation of ^{14}C from acetate into embryo lipids was very rapid with phospholipids and 1,2 diglycerides highly labelled in treatment times as short as five minutes. Phospholipid radioactivity was largely associated with choline glycerophosphatide. In short treatment times oleic acid had the highest specific activity. Malonate or CO_2 increased the labelling of saturated fatty acids in embryos as compared to endosperms. Stearic had the highest specific activity of the fatty acids, in endosperm and whole seeds.

Nutritional Studies

The limited incorporation of erucic acid into tissue lipids of animals given rapeseed oil as dietary constituent can be explained by partial β-oxidation of erucic acid to eicosenoic and oleic acids. A synthetic dietary oil containing cetoleic acid (11-docosenoic) was fed to rats and the 9-eicosenoic and 7-octadecenoic acids were found in the tissue lipids confirming the partial β-oxidation mechanism.

A nutritional evaluation of Canbra oil (zero erucic rapeseed oil) was also carried out in conjunction with the Food and Drug Directorate, using rats as the test animal. Food consumptions and weight gains were similar to those found with olive oil or a mixture of olive oil and lard. No enhancement was found by the addition of saturated fatty acids, indicating that Canbra oil is nutritionally satisfactory.

A nutritional study on the interrelationships between type and level of carbohydrate was carried out on mice. Mice fed sucrose and fructose at high levels developed fatty livers. Those fed fructose ate less feed and fattened more slowly than with glucose, sucrose or cornstarch fed at the same levels. Mice fed galactose ate more feed but had the poorest growth rate. The difference in responses was reduced as the level of carbohydrate decreased at the expense of dietary fat.

Carbohydrates

A method has been developed for chemotaxonomic studies of yeasts, based on the H-1 proton magnetic resonance spectra of the mannose-containing polysaccharides of the cell walls, which are purifiable by

their insoluble copper complexes. Of 410 different yeasts examined, 150 different spectra were obtained, each representative of the typical chemical structures of the polysaccharides.

Methods have been developed to facilitate characterization and classification of mannose-containing polysaccharides in terms of their main-chain and side-chain structures. About 30 polymers have been thus examined.

Polysaccharides with α-(1→6)-D-mannopyranose main-chains often have side chains which can be removed by action of an α-D-mannosidase from *Arthrobacter* sp. GJM-1. Those with β-D-mannopyranose and D-galactopyranose units in the side chains are enzyme resistant, but can be degraded to their main chains following partial removal of side chains with acid.

G.l.c. methods for methylation-fragmentation studies on polysaccharides have been developed. Methyl glycosides of *O*-methyl derivatives of mannose can be separated free or as their t.m.s. derivatives, and identified by comparison with standards. The synthesis of the possible standards was facilitated by use of the $LiAlH_4$-$AlCl_3$ reagent which converts benzylidene and methylene acetals to *O*-benzyl and *O*-methyl ethers respectively. The *O*-methyl derivatives of 2-deoxy-2-methylaminoglucose have been prepared in order to characterize the amino sugar units in the 2-acetamide-2-deoxy-D-glucomannans of *Pichia bovis* and *Saccharomyces phaseolosporus*.

P.m.r. spectroscopy has been utilized in the identification of β-links in certain yeast mannans. β-linked mannoypranose units give H-1 signals with chemical shifts of τ4.5–5.0, higher than those from the more common α-linked units.

The locations of acyl groups in the glycolipids of *Ustilago* spp. was done by (1) blocking the free hydroxyl group with *O*-(1′methoxyethyl)-groups, (2) removal of acyl groups, (3) methylation, (4) hydrolysis, (5) identification of the resulting *O*-methyl ethers.

As an aid in methylation-fragmentation analysis of the 2-acetamido-2-deoxy-galactogalactan from *Aspergillus nidulans*, the g.l.c. characteristics of *O*-methyl galactoses and derivatives have been determined and several *O*-methylated 2-acetamido-2-deoxygalactoses synthesized.

Plant Extractives

Analysis of volatile conifer leaf oils has been extended to provide quantitative data for different populations of the same species. A pilot study involving *Juniperus virginiana* populations over a 1500 mile transect of its typical range has been completed and the data obtained were used to derive a numerical classification method which can detect minor genetic differences within the same species (joint project with University of Texas). A cline was found to exist for the red juniper, the largest deviation from the typical terpene distribution pattern being found at the periphery. This juniper has been reported to hybridize extensively with *J. ashei* in Oklahoma and Texas, but chemical analysis did not confirm this. The leaf oil of *J. virginiana* contains mainly terpenes of the sabinane and eudesmane groups as well as several aromatic ethers of the sapole type and methyl vinyl anisole, which has not been isolated before. In contrast, *J. ashei* contains mainly terpenes of the camphane-borneol group and no aromatic ethers, making differentiation of the two species and their hybrids a relatively easy task. Subsequent detailed morphological analysis confirmed that introgression between these two species does not occur. The leaf oil of the common juniper has also been analyzed and it too can be employed in chemosystematic studies. An improved separation technique for the analysis of the very complex leaf oil of the yellow (Alaska) cedar was devised and many new minor constituents, including two new diterpenoids, 8-epi- and 8-,13-diepimanoyl oxide, and esters of C_5-branched chain acids and alcohols were isolated.

The basic requirements for chemotaxonomic investigations involving terpenes have been summarized. Individual and populational variability in Engelmann and Sitka spruce, as well as jack and lodgepole pine are being studied to obtain further insight into the phylogeny of these conifers. Analysis of the leaf oil of Engelmann spruce populations from the timberline of the Rocky Mountains of Alberta indicates that the severe ecological conditions at the limit of a species impose special genetic conditions, as far as the terpene distribution pattern is concerned (joint project with University of Calgary). Isolated spruce and pine populations are now being studied to obtain more information on this aspect. Another project involves the analysis of the leaf oils of the coastal and interior varieties of the Douglas fir.

Aspects involving the anomolous behaviour of cyclic terpenes in the oxidation with permanganate-periodate, as well as other techniques which can be of use in the analysis and identification of terpenes, have been investigated.

Proteins

Research on the non-enzyme seed proteins of rapeseed (*Brassica napus* L. and *Brassica campestris*, L.) has been extended to some of the other members of the genus. The major objective of the work remains the elucidation of the mechanisms of protein biosynthesis and deposition in the seed. At present, three

topics, which are prerequisites to the biosynthetic study, are under investigation. They are: (1) characterization of the two major protein constituents of the seeds with regard to subunit dissociation, molecular size, and N-terminal and amino acid compositions; (2) patterns of protein inheritance when two varieties or species are crossed (carried out in conjunction with Canada Department of Agriculture); (3) the effects of soil nutrient deficiencies on the relative proportions of the seed components.

The results from part 1 have shown that all species examined contain globulins which act as single molecules under specified conditions, have large molecular weights, and are composed of several polypeptide chains. These globulins dissociate into subunits at low pH; one of these is a glycopeptide whose neutral carbohydrates are glucose and arabinose. All species also contain a low molecular weight protein which is strongly basic. These two proteins represent 35–45% of the seed protein. The chromatographic and electrophoretic properties of these proteins from two species (*B. napus* L. and *B. campestris* L.) are almost indistinguishable. However, the species differences in proteins of similar physical properties reside in their amino acid compositions and their relative amounts in the seeds. These differences permit tracing of the patterns of protein inheritance in progeny after two species or varieties of rape have been crossed.

Nutrient deficiencies in the soil reduce the amounts of these two proteins in the seed and also change the relative proportions of the other seed constituents. For instance, protein content is much reduced by a soil sulfur deficiency but the reduction is not reflected in the total nitrogen figures. The mature seed contains larger amounts of free amino acids and low molecular weight peptides than one finds under normal conditions of nutrient supply. The results indicate there is a relationship between the amounts of certain low molecular weight compounds (glucosinolates) and the amounts of proteins in the developing seed.

Engineering and Process Development

Ecology, Taxonomy and Metabolism of Yeasts

Studies of the yeasts in the Saskatchewan River at Saskatoon showed that the population of these organisms downstream from the city was 10 to 20 times greater than upstream, with at least 20 yeast species contributed to the river from the sewage.

Studies of the yeast population of the soils at the International Biological Program site at Matador, undertaken in conjunction with studies of the soil microflora by the University of Saskatchewan, showed that the numbers of yeasts averaged 5,000 to 10,000 cells/gm., and were more numerous in the upper 10 cm. of soil. Most of the cultures isolated were *Cryptococcus albidus* and its variety diffluens. A few cultures of *Cryptococcus laurentii, Cryptococcus dimmenae* and *Sporobolomyces* species were found.

The biosynthesis of hydroxy fatty acid sophorosides by *Torulopsis bombicola* sp.n. was investigated in whole cells and cell-free extracts, in co-operation with Dr. A. P. Tulloch.

The use of p.m.r. spectroscopy of yeast mannans and mannose-containing polysaccharides as an aid in identification and classification of yeasts was further developed. Characteristic spectra for most known yeast species were obtained, and used for placing the species in groups. Reasonable agreement with taxonomic groups obtained by classical methods was obtained, and relationships suggested by some of the p.m.r. spectra agreed well with those obtained by other workers using DNA-RNA and DNA-DNA homology and antigenic analysis. The spectra were also used in the identification of unkown cultures from various sources, in determining phylogenetic relationships among some new species of *Hansenula* and in grouping the fungal plant pathogens, *Ceratocystis* and *Graphium*. These fungi, unlike some other filamentous species, produce rhamnomannans and glucomannans which give characteristic p.m.r. spectra.

Culture of plant cells in stirred fermentors was begun. Soybean cells have been grown successfully in cultures up to 20 liters.

Continuous Fermentation

Further development of the continuous phased culture technique has produced another method of operation, displacement phasing, which has been successfully adapted to pilot scale operation.

The displacement method is a versatile technique for *in vivo* research of cell growth and metabolism. The new method is especially useful for investigating the influence of nutrient on the growth of the cell and can economize on substrate during periods of reduced operation.

The new techniques have been used mainly with *Candida utilis*, for cell studies, though other studies have also been made with a *Pseudomonad* species for aromatic breakdown and a *Bacillus* species for production of extracellular enzymes. Currently the technique is being used with species of *Azotobacter* and blue green algae in nitrification studies.

Studies with *Candida utilis* have established the variability of cell performance and demonstrated a need for developing new methods for cell examination and analysis. It has been found that monitoring the oxygen uptake of the culture is excellent for studying cell metabolism and physiology. Other studies with ^{32}P and ^{33}P have been made on cells grown under carbon, nitrogen and phosphorus limitation. The cells, grown at the same rate and on virtually the same medium except for the limiting component, showed very different patterns of phosphate composition during the cell cycle and during the post-cycle period.

Cultivation of Plant Tissue Cells

Plant tissue cells grown in shake flasks or conventional fermentors have the tendency to form cell clusters, which are a very unsuitable material to investigate physiological or biochemical behaviour. A fermentor has been designed, based on a new principle, which allows the cultivation of tissue cells in single, double or quadruple cell units. Presently this fermentor type is employed as a chemostat for the cultivation of tissue cells derived from soybean roots and wheat. Further investigations will show if this culture system is adaptable for the synchronization of tissue cells, necessary to investigate the symbiotic and parasitic relationships between plants and microorganisms.

Oxygen Transfer

The transfer of oxygen from air to liquid media is an important process in the pharmaceutical and fermentation industries and in sanitary engineering.

By employing a tubular fermentor rotating in a horizontal plane, we have shown that oxygen transfer results from two distinct mechanisms operating simultaneously. The first, absorption, is recognized as resulting from diffusion of oxygen molecules through the liquid surface, the normal solution of a gas by a liquid. The second transfer mechanism, adsorption, results when oxygen molecules are adsorbed on the liquid surface. In all probability, this adsorption must occur before any absorption transfer can take place. In addition, if this adsorbed layer of oxygen molecules is forcibly submerged, an appreciable amount of oxygen is physically trapped in the liquid and can be used to increase the amount of biological or chemical oxidation in the liquid. Under conditions of high surface turnover with a relatively small total surface area exposed, it has been shown that the majority of oxygen transfer results from the adsorption mechanism.

This new theory for gas-liquid mass transfer has been proven using rotating horizontal fermentors, shaken flasks, and cyclone fermentors. This study has shown that more efficient oxygen transfer results when the percentage of oxygen in the sparged gas is increased than when the fermentation vessel is pressurized to give the same partial pressure of oxygen in the gas phase.

Oil Seeds

Work has continued in cooperation with the Department of Agriculture on the reduction of thioglucosides in rapeseed and mustards through plant breeding. A sample of Echo rapeseed was separated according to size and seed coat color. The yellow seeded material averaged 8.7% crude fibre and 40.2% protein in the meal and the brown seeded material 13.3% and 37.2% respectively. There was also a significant increase in oil content in the yellow seeded type.

Meals were prepared in the pilot plant from a number of commercial and non-commercial varieties of rapeseed and Oriental mustard, in a manner similar to that used in industry, to determine the effect of the various thioglucosides in animal nutrition.

Plant Proteins

Attention has been given to increasing the production of field peas as a source of protein. Predominant varieties average 24 to 25% protein and contain about 55% starch. A rapid colorimetric protein determination was developed and used to analyze available samples grown in the cooperative tests from 1966 to 1968 in Western Canada. There were significant variations with stations and with years and a significant variation with variety indicating that higher protein types can be developed. Protein contents of 500 introductions from the world pea collection grown at Morden, Manitoba in 1965 ranged from 22 to 32%. The protein is an excellent source of lysine and appears to be nutritionally adequate in all other essential amino acids except methionine. Nutritional studies at the University of Saskatchewan showed that peas were an adequate protein supplement in swine rations without additional methionine. Preliminary cost estimates indicate that feeding of peas would be economical if grown and fed on the farm, but inclusion in feed manufacturers' formulas would depend on availability and the price at which they would enter linear programmed least cost rations. Since protein is more costly than energy in feeds, higher protein varieties would be more valuable.

Pea flour was separated by a wet extraction process into a protein fraction (36%) with 65% protein and a starch fraction (64%) containing 1.8% protein and 87% starch.

Feeding the pea protein concentrate (P.P.C.) to mice at the University of Saskatchewan gave inferior results because of the methionine deficiency. Supplementation with methionine in P.P.C. diets containing 15% protein gave growth rates and biological values equal to those with egg, F.P.C. or methionine-supplemented casein.

The starch fraction was tested as a distiller's adjunct by a commercial firm using potato starch as a control. In general, the cooking of the pea starch was not as difficult as with potato starch, final balling was 0.0 and 3.0 respectively and alcohol yield 3.9 and 2.7 gallons per bushel respectively. The pea starch did not contribute to the flavor of the distillate. Preliminary trials also indicate the starch would be satisfactory as a brewer's adjunct.

Collaborative work in the area of human foods from pea flour or pea products is underway, including incorporation of pea flour or protein concentrate into bread and spaghetti and the preparation of textured meat analogues from the protein concentrate.

Fibrous Products

The addition of small quantities of sodium hydroxide during pulping of poplar wood gave the

operators of a commercial fibreboard plant better control, and the plant is now able to manufacture products having a wider range of properties.

A thorough study was made of pulping methods using ethylene glycol to extract lignin. Hot ethylene glycol alone will remove only 25–30 percent of the lignin but greater quantities can be removed if pulping is carried out under acidic conditions. A comparison of the properties of hand sheets made from ethylene glycol pulp and commercial sulfite and kraft pulps show that the ethylene glycol pulps are similar to the sulfite pulps but lower in strength than the kraft pulps.

Waste needles and branches of conifer trees were pulped by the Asplund process and fibreboards and hardboards were made from the pulp. A roof insulation board was made that met Canadian Government standards of strength and water sorption. Hardboards made from this material would not meet Government standards.

A laboratory program was set up to investigate the use of jack pine wood to make fibreboards. Two main problems encountered by a local commercial plant were: (1) difficulty of obtaining desired board strengths; and (2) spontaneous ignition of the boards in the direct fired tunnel drier. Data obtained during pulping trials showed that the strength of the jack pine fibreboards increased if increased amounts of NaOH were used for digestion. When 6% NaOH was used foam produced by saponification of the resin and fatty acids interfered with board formation, but the soaps were readily removed by washing the pulp, and board strengths were doubled.

Studies have also been undertaken to examine the extractives of jack pine wood and to find the effect of common cooking agents on these extractives. The heartwood fraction of a jack pine log contained 3.4 percent acetone soluble material while the sapwood only contained 0.9 percent extractives. Gas chromatographic analysis of the silylated heartwood extract showed eleven compounds in appreciable amounts including pinosylvin, pinosylvin monomethyl ether, levopimaric, abietic, pinocembrin and pinobanksin, as well as numerous other trace compounds. The sapwood extract contained fewer compounds.

The effect of cooking agents on the extractives is being investigated. When jack pine wood is pressure digested with 22% NaOH, the more volatile compounds are removed as well as a large percentage of the more complex compounds such as pimaric, pinocembrin and pinobanksin.

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The Division of Physics now includes the former Divisions of Applied Physics and of Pure Physics. The objectives of the Division are threefold:

(a) To increase the understanding of physics in those areas where the Division has a special competence;

(b) To provide Canada with physical standards of the highest quality, to compare Canadian standards with those used in other industrial countries and to calibrate measuring instruments for industry, government and educational institutions;

(c) To improve the industrial and social climate of Canada by providing advice and information to industry and governments and by providing designs for new industrial products.

The Division is divided into a number of sections and in the following report the activities of the various sections are outlined. Some of the sections overlap to a considerable extent in their areas of interest but they are maintained in their present form for administrative convenience. The major areas of activity are acoustics, cosmic rays and magnetospheric particle studies, high energy particle physics, plasma physics, metal physics, molecular physics, photogrammetry

and the development and use of basic physical standards. The various areas of activity and the internal organization are not simply related to the objectives of the Division. For example, on the one hand, the standard laboratories can not advance unless they undertake long range investigations designed to obtain a better understanding of physics in areas relating to standards and, on the other hand, their activities have generated new designs for commercial instruments. Few scientists in the Division confine their interests to one of the objectives of the Division and this interlacing of various activities has contributed much to the productivity of the staff.

The contributions of the Division to Canadian science, industry and government have appeared in a number of forms. The standards laboratories have met a number of statutory requirements by calibrating secondary standards for departments which are concerned with enforcing legal standards and in addition have issued over 300 calibration reports per year for instruments used by industry, government and universities. To meet the needs of trade and standards associations for specifications for products and test procedures, much further work has been carried on in the standards laboratories. A considerable portion of the time of the staff is spent serving on a wide variety of committees dealing with scientific and technical matters. Less visible but equally important is the large amount of time spent in answering questions and giving advice on technical problems. Finally there is the large volume of work published in well established scientific and technical journals, which is recorded at the end of this report.

Acoustics

Physiological and Psychological Acoustics

The early detection of hearing loss due to noise exposure is limited by the poor accuracy of conventional audiometry at frequencies greater than 3 kHz. (At 6 and 8 kHz, for example, the standard deviation of conventional measurements is 4 dB.) The key to better accuracy lies in the acoustic coupling between the sound source and the external ear. Five normal modes of the external ear have been recognized: the fundamental canal resonance M1 at 2.9 kHz, the depth resonance of the concha M2 at 5.5 kHz and higher modes M3, M4 and M5 at 9, 11 and 13 kHz which are related to transverse modes of the concha. M2 has a strong monopole interaction with the sound field while M3 and M4 have dipole properties which explain some important angular effects at the higher frequencies. Ducted sound sources have been devised which produce highly uniform progressive waves between 3 and 15 kHz and the interactions between these sources and a model ear have been studied.

In the field of psycho-acoustics, studies have been under way for some time of binaural acoustic image phenomena which seek to elucidate the human processing mechanism of acoustic stimuli and also have relevance to the more readily appreciated field of stereophonic sound reproduction and listening. Since frequency band width of signals has an important bearing on acoustic image formation, a constant interest has to be maintained in loudspeakers and their performance. In experiments using loudspeaker sources in an anechoic room, listeners reported convincing in-head and external localizations which were perceived separately and in combination. The amount of in-head localization was found to change substantially and systematically with changes in signal band width and source position. Signal type and centre frequency had less effect. Experiments in which head movements were progressively restricted showed that small, involuntary head movements can only be of slight importance, if any, in the "externalization" of sounds.

Similarly it has been found that front-back discrimination can be dominated by certain characteristics of the signal. Some subjects demonstrated front-back localizations which were almost entirely dependent on source position; in others it depended on signal band-width but was substantially independent of source position.

Community Noise Problems

The statistical distribution of road traffic noise has included measurements on about 3000 vehicles divided into groups as follows: motorcycles, passenger cars and small trucks, intermediate trucks (6,000 lb. to 15,000 lb.), and heavy trucks including tractor trailers. More limited measurements have been made on snowmobiles, power lawn mowers and air conditioners. Some work has also been done on the ad hoc silencing of some of these to determine the extent to which the noise can be reduced without major redesign of the machine.

Since motor vehicles represent the dominant source of background noise in the community, some studies have been carried out on the effect of these sources on the background noise in a zone which is relatively free of sources (a residential area) when the size of zone, number of vehicles, size of city etc. are varied. Continuous recordings of actual levels of background noise have also been made by using a recorder with a slow writing speed. The results check reasonably well with those calculated provided that a constant terrain effect of 12 dB is taken into account.

To avoid the use of subjective assessment of noise when setting limits, a program is under way to determine the effect of noise on sleeping subjects as evinced by an electroencephalograph. When noise from a passing truck is used there is still a substantial probability (about 15%) that a shift in sleep level will

be induced with peak noise levels of 40 dBA. Short tone bursts are also used as stimuli and substantially higher thresholds are the result. This is believed to be relevant to response to sonic booms.

High by-pass ratio aircraft engines are the rule nowadays and while substantially reducing the noise of the jet they have accentuated the whine of the compressor. It has been shown that this can be reduced by putting steps in at least that edge of a stator blade which is closest to the rotor.

Legislative Control of Noise

Considerable time has been spent in the last two years advising municipalities and other legislative bodies on the feasibility of noise control by legal means. Legislation in other countries has been studied and so have instruments for their suitability in law enforcement. A roadside sound level meter with a lighted display unit has been designed and built for the purpose of educating the public in this field, as well as enabling them to test their vehicles under various operating conditions. It is concluded that for the present the actual noise made will have to be controlled by instruments in the field, rather than attempting to regulate the noise capability of the machine, although the latter will eventually be necessary at the manufacturer's level.

Ultrasonics and Molecular Acoustics

To improve the credibility of the molecular models used to predict conformational energies (and hence rates of chemical reaction) for flexible organic molecules, the study of the ultrasonic relaxation in methyl cyclohexene has been extended to a number of liquids whose molecules exhibit a single variant from this basic structure. The double-bond in methyl cyclohexene, and carbonyl oxygen in methyl cyclohexanone, are both found to lower the barrier to inversion of the chair form of the ring in an approximately predictable manner. Inclusion of a nitrogen atom in the basic ring, as in methyl piperidine and methyl piperazine, appears to lower the energy of the elusive boat conformation of the ring sufficiently to make this form accessible, apparently for the first time, to physical measurements in comparatively simple molecules. The reason for the decrease in energy is not clear at present.

The understanding of acoustic relaxation phenomena, achieved in projects such as the one described above, has been applied to community noise problems. The absorption of sound in air for the ranges of frequency, temperature and pressure of practical interest can now be derived by extrapolation from the very limited range of reliable measurement. It turns out that for relative humidities $> 25\%$ and temperatures $> 10°C$, in which most people live, the dominant mechanism of sound absorption in air over a major portion of the audible frequency range is the vibrational relaxation in nitrogen, not oxygen as supposed hitherto.

To obtain detailed information about the elastic constants of solid materials it is necessary to measure, with considerable precision, the phase velocities of waves that are propagating along directions which are usually related to the internal structure of the specimen. An instrument based on the "sing-around" system has been constructed which can record environmentally induced velocity changes of about one part in 10^6. When making absolute velocity measurements a more complex version of the apparatus is used, involving a stable delay line in series with the specimen to reduce the interference between acoustic wave trains. The results of a study of the second order elastic constants of germanium should indicate the success of this arrangement.

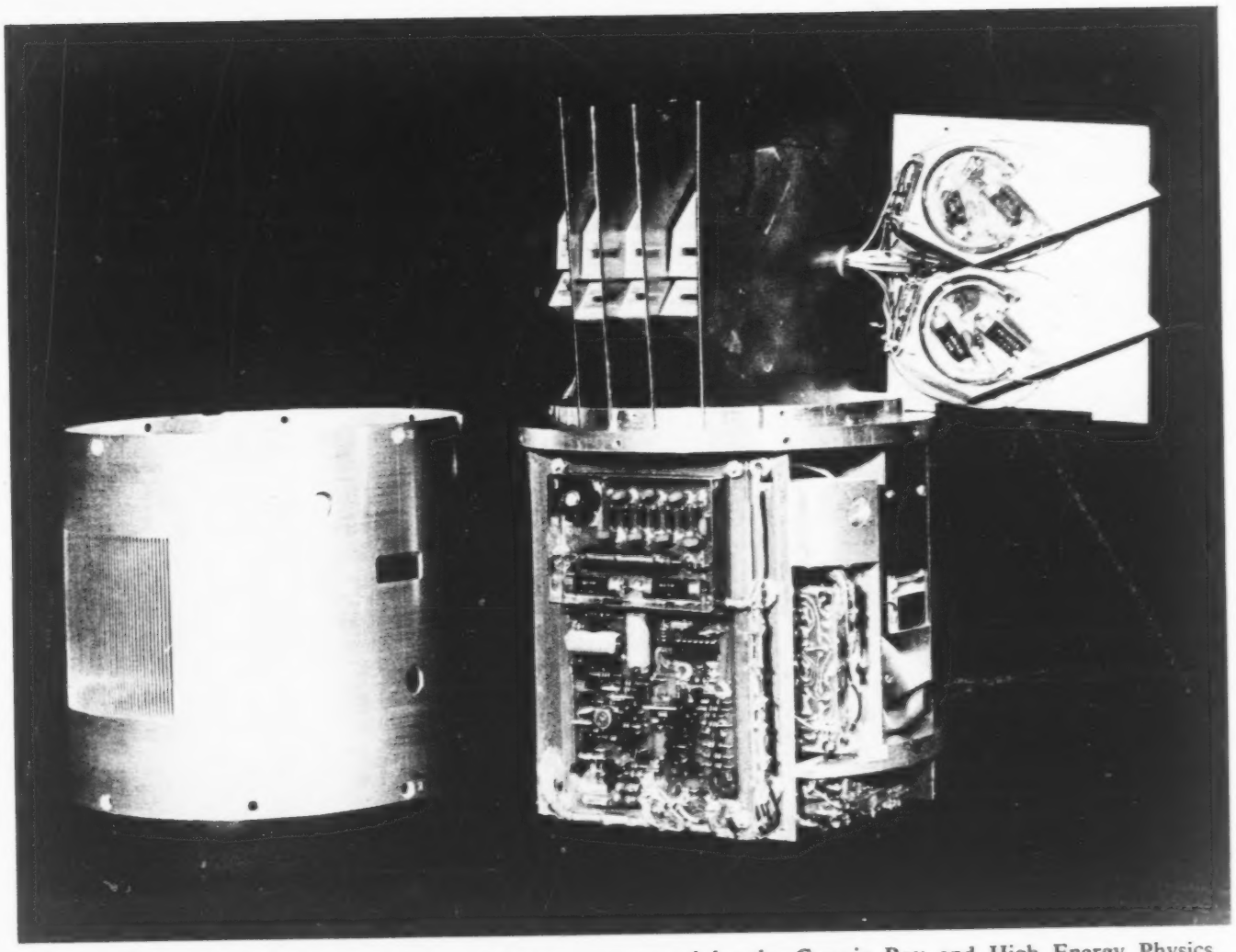
Cosmic Rays and High Energy Particle Physics

Space Radiation Studies using Rockets and Satellites

Experiments on board the Alouette-ISIS series of satellites and on rockets flown from Fort Churchill and Resolute Bay are being used to study the properties of charged particles in the earth's magnetosphere (the region around the earth controlled by the earth's magnetic field).

The main objectives of this work are: (1) to understand the nature of the interaction between low energy solar particles (the solar wind with energies in the ev to Kev range) and the earth's magnetic field; it is this interaction that transfers particle energy from the sun to the earth and is ultimately responsible for the Van Allen radiation belts, the aurora, magnetic storms, ionospheric disturbances, etc., and (2) to determine the location and nature of acceleration mechanisms which operate within the magnetosphere and permit the low energy solar plasma to generate the higher energy particles found in the radiation zones and aurora; the energization of charged particles in magnetized plasmas is probably a fundamental process that occurs throughout the universe and plays an important role in solar flares, radio galaxies, pulsars, the generation of cosmic rays, etc.

Recent studies with Alouette II have led to a determination of the high latitude limit of "closed" (i.e. dipolar) geomagnetic field lines. The limiting latitude, where field lines are closed to the opposite hemisphere, shows a strong dependence on local time occurring at appreciably higher latitudes at noon and dawn than at midnight and dusk. The magnitude of the polar cap magnetic flux, which lies on field lines that "open" into the geomagnetic tail, is a measure of the strength of the interaction between the solar plasma and the magnetic field. By measuring the size of the polar cap region where field lines are "open" as a function of the orientation of the geomagnetic axis, it has been shown that the solar plasma-geomag-



A typical array of electron and proton detectors constructed by the Cosmic Ray and High Energy Physics Group. These detectors are flown in rockets to measure the characteristics of auroral particles.

netic field interaction depends on the angle between the geomagnetic axis and the solar wind direction, and that the interaction is strongest when this angle is 90°. This leads to important clues as to the nature of the interaction.

Other recent Alouette II investigations have compared near simultaneous measurements of electron intensities at different locations in the magnetosphere and this has led to a mapping of the locations of the predominant magnetospheric acceleration mechanisms.

Future analysis of satellite data will continue to use Alouette II measurements and also ISIS-A measurements which are now becoming available and which cover a larger energy range with better energy, time and angular resolution. One study will use simultaneous measurements from both satellites in an attempt to separate spatial and temporal variations. ISIS-B, which will have still better energy coverage and resolution, is being fabricated at present and will be launched in early 1971.

Recent rocket measurements of intensities, energy spectra and pitch angle distributions of electrons, protons and α-particles associated with magnetospheric substorms have made it possible to infer some of the properties of particle acceleration mechanisms and to construct a model which, at least qualitatively, describes the sequence of events which lead up to the production of energetic particles. However, the physical process actually responsible for the acceleration is still not understood and this remains the outstanding problem to be solved in the field of magnetospheric physics.

A number of new rocket experiments are planned which will attempt to (1) use particle pitch angle distributions to measure static electric fields associated with auroral substorms, (2) correlate particle intensity variations with VLF radio measurements and (3) measure spectra and relative abundances of heavy ions at low altitudes and compare with similar measurements in solar wind.

Cosmic Rays

The general objectives of the cosmic ray studies are two fold: first, to determine the properties of the interplanetary medium and secondly, to understand

the mechanisms involved in the entry of galactic cosmic rays into the solar system. Work in this field is currently concentrated on two problems concerned with the streaming and modulation of cosmic rays in the solar system.

1. The Heliocentric Gradient of Cosmic Ray Intensity

Models of the cosmic ray modulation process postulate a region around the sun, the heliosphere, inside of which irregularities in the large scale interplanetary field are driven radially outward by the solar wind. The interaction of the cosmic ray gas with these irregularities sets up a cosmic ray density gradient within the heliosphere, the density decreasing with distance as one approaches the sun. Several direct space probe measurements of the gradient were made in the period near solar minimum (1964–66). At the lower energies there is wide discordance between the various measurements; the one measurement at higher energies yielded a surprisingly large value for the gradient.

Cosmic ray neutron monitor data can provide an independent estimate of the local density gradient at high energies. An analysis of the latitude dependence of the cosmic ray intensity changes associated with interplanetary magnetic field reversals has given estimates of the gradient for periods between 1964 and 1968. It is found that at solar minimum the gradient is at most 1/5 as large as that quoted from the space probe measurement. As expected, the gradient has increased with increasing solar activity, but is still a factor of 2 lower than the space probe value at solar minimum.

2. Cosmic Ray Anisotropy due to Field Aligned Streaming

The effect of cosmic ray streaming along the interplanetary magnetic field on the diurnal variation of intensity observed by ground based cosmic ray monitors is being investigated. About three years (1966–68) of data has been obtained consisting of hourly averages of the interplanetary magnetic field components, as measured by instruments on Explorers 28, 33 and 35. For this period, the average cosmic ray anisotropy in the ecliptic plane is determined for each day from the daily variations in counting rates of a network of six neutron monitors distributed more or less uniformly over 360° of asymptotic longitude. The results show that there is a significantly greater variation of the daily average anisotropy along a direction close to that of the average interplanetary field than along other directions. Further, when the field strength is greater than average the field aligned component of the anisotropy is considerably larger, and can be observed to follow the transient variations of the daily mean field direction.

An attempt is being made to fit this result into a picture in which the net streaming is composed of three components-radial convective streaming with the solar wind; streaming along the magnetic field lines driven by the vector component of the radial gradient parallel to the field; streaming perpendicular to the field due to random walk of the field lines.

High Energy Particle Physics

Research activities in high energy particle physics come under three headings: muonic atoms, boson spectroscopy and very high energy interactions in emulsions. Work in the first two of these is carried out in collaboration with experimental and theoretical physicists at Carleton University.

Attempts to find a nuclear shape that is consistent with very precisely measured energy levels in muonic Pb^{206} have led to a study of some of the smaller effects. Transitions to and from the $2S_{1/2}$ level, first observed by this group, are currently being measured for the lead isotopes 204, 206, 207 and 208. Their determination will help to establish the amount of nuclear polarization by the muon and separate polarization effects from the static nuclear shape effect. Other measurements will check higher order vacuum polarization and electron screening corrections. Radiationless transitions in muonic lead and bismuth are being studied further by observing the γ-rays and neutrons resulting from excitation of the nucleus.

The spectrum of bosons (x) produced in the reaction $p + p \rightarrow d + x^+$ was measured by the group in 1968. Cross-sections for pion production ($x = \pi$) and proton production ($x = p$) have been determined. Other bosons are difficult to detect, so that only upper limits of cross-sections can be determined. The group intends to do further work on $pp \rightarrow \pi d$, in view of its fundamental importance, and perhaps then move into the area of strange bosons.

The properties of the interactions of high energy light nuclei ($1 \leqslant Z \leqslant 10$) are being studied in nuclear emulsion which has been exposed to the primary cosmic radiation. At the present time interest is concentrated on the apparent anomalous interaction probability of some secondary fragments produced in these interactions.

Diffraction Optics

For the past two years, the Diffraction Optics section has developed the previously undertaken research, whose objectives are:

1) to obtain a better understanding of the nature of light and of diffraction;
2) to use diffraction theories as tools to enhance the resolution of optical instruments;
3) to apply improved optical systems to various fields of optics and particularly to metrology;
4) to improve special photographic techniques such as "dodging".

A more detailed summary of the work is presented below.

Study of Fundamentals in Diffraction

A broad theoretical study of diffraction was made to determine what experimental areas would be profitable in developing, firstly, a better understanding of the nature of light, and, secondly, a practical enhancement of optical instrument resolution. Some experimental work is already under way: high precision measurements of diffraction patterns are being made in order to get accurate data, which will most probably contribute to diffraction theory.

Diffraction of Microwaves

Microwave facilities are being established to obtain experimental data concerning diffraction which cannot be easily obtained with light.

Detailed plans for a first experiment in microwaves are now completed. Basically, spherical wavefronts radiated from a point source will be focussed by an aberration-free lens, and the image space will be scanned with a probe. Very accurate measurements of amplitude and phase will give data for verifying theoretical hypothesis about diffraction and image formation.

An operating frequency of 60 GHz has been chosen for the microwave system. A very rigid frame has been made for providing a stable coordinate reference system for the various components: source, lens and scanning probe. The rigidity of the structure must be such that the distances between any arbitrarily chosen set of points located anywhere upon it remain constant to within 10 microns. A data acquisition and measurement system includes all of the instrumentation necessary to measure and record the amplitude and phase of the microwave field at some arbitrary point in the object or image space, and the x, y, z, coordinates of that point. The microwave field will be completely contained in a chamber in which spacious reflections will be inhibited by walls made of microwave absorbing material.

Diffrimascopy

Diffrimascopy is a field of optics which involves image formation by means of diffracted light.

A particular case of a diffrimascopic system has been set up to study images of opaque objects. The object is coherently illuminated. The light rays touching the object contour are diffracted and then transmitted through an optical system, which firstly focusses these rays into an image of the object contour, and secondly cuts out all light other than diffracted light. The resulting image is a diffrimascopic image. Compared to a conventional image, it is unusual. Along an axis, normal to the contour, the distribution of light is symmetrical. The luminous intensity is zero at the centre of symmetry, which accurately represents a point of the geometrical-optics image. These characteristics hold when the image is observed out of focus. Moreover two diffrimascopic images equally out of focus, inside and outside the focus, are identical.

Characteristics of diffrimascopic images make metrological pointings much more accurate than with any conventional optical system. Industrial applications are anticipated, and particularly the principle of a "profiloscope"—a diffrimascopic profile projector —has been considered.

Amplitude Filters and Flux Selectors

In the observation plane of any optical system the image of a point source is never a point, but a diffraction pattern. As a result the optical system has a "resolution limit" which is proportional to the size of diffraction patterns, enhancing the resolution of the optical system.

The Diffraction Optics Section has succeeded in enhancing the resolution of lenses by means of amplitude filters, and of flux selectors. An amplitude filter is a coating on one of the surfaces of an optical system, which locally varies the light transmission so as to produce a non-uniform illuminance at the exit pupil of the optical system. This non-uniform illuminance is made to conform to a distribution theoretically calculated to give maximum resolving power. A flux selector is a particular amplitude filter, whose coating consists of a geometrical arrangement of opaque zones separated by fully transparent areas.

This project is of importance, not only in the development of optics theory, but also for the improvement of optical technology in industry. Applications are being made to microscopy.

Photographic Dodging

The Diffraction Optics section needs photographic dodging with a gross contrast reduction of 1000 to 1, which cannot be obtained with commercial dodging printers. A prototype of a high performance dodging printer was designed and built.

Electricity

In the two year period under review our knowledge of the base values of emf and resistance has improved at least ten-fold, so that our volt is known to about $\pm 0.05\ \mu V$ and the ohm $\pm 0.1\ \mu\Omega$. By new international agreements through the BIPM, 10 nations altered their reference values on 1 January 1969 so that they all agreed, for the units of emf and resistance, to within 1 μV and 1 $\mu\Omega$ respectively.

Low resistances have been studied by the use of the current comparator bridge yielding determinations which are better by a factor of between 10 and 100. Improvement has been made in the physical standards themselves by changes in design which eliminate a number of small errors due to thermal effects. High

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valued resistors in the teraohm region have been investigated by new methods of high accuracy which in one case has resulted in a patent on a semi-automatic technique of measuring these resistances absolutely.

Improvements in techniques for capacitance and inductance determinations have resulted in a better knowledge of the primary base unit of capacitance and in a ten-fold increase in the accuracy of the inductance scale. Impedance measurements, in general, have been improved, particularly in the case of ac/dc transfer determinations which form the basis for power measurements. Extensions to range and frequencies (up to a maximum of 100 KHz) available have been effected and the laboratory is now in a better position to serve Canadian industry.

As one part of the general improvement in operation greater use is now made of computers for calculations and for report writing, resulting in economy of staff time. Generally speaking, emphasis is placed on developing automatic methods of measurement which will minimize staff time without sacrifice of accuracy, indeed with achievement of improved accuracy—a trend which will no doubt continue. Two scientific workers from the NPL (India) were attached to the laboratory for specialized training in electrical precision measurements.

After preliminary study and planning, experimental work was started in September 1969 to utilize the Josephson effect to ensure the stability of the unit of emf by comparing it to a known frequency of high stability. The methods are being investigated by other labs independently and great hopes are held out for a useful innovation from this research.

Much work was done in connection with the consultative committees of the BIPM for electricity, for high frequency, for the definition of the second, and for the Twelfth General Conference on Weights and Measures. The latter secured agreement on several scientific points including the definition of the second.

In the realm of frequency and time measurements caesium beam resonators and hydrogen masers continue to be the focal point of laboratory interest. The frequency stability of the masers having been shown to exceed 1 part in 10^{14} was utilized to re-evaluate the performance of the long beam (2.1 m) caesium resonator, NRC's primary standard. The accuracy of this standard (Cs III) is now given as 1.5×10^{-12}, (which represents the accuracy for NRC's realization of the definition of the second). Figures from the Bureau International de l'Heure indicate a less conservative number, because the International Time Scale formed from the mean of six national laboratories and that of NRC agree to within about 1 μs per year (i.e. less than 1 in 10^{-13} in frequency).

To achieve the improvements in the time standards, much ancillary work was done on crystal oscillators, on special synthesizers, on servo-control circuits, on phase comparators, on VLF and Loran-C measurements. Data reduction and monthly reports have been simplified by use of the computer. Work was also done on a double beam caesium tube which, despite early promise, proved disappointing. Another standard resonator is under development to supplement Cs III. The work on hydrogen masers led to a value of the hydrogen frequency in terms of caesium which agrees to within 1 part in 10^{12} of the mean of other published results.

As it was apparent that comparisons of frequency alone were becoming too imprecise for reference to other distant clocks, a start has been made in 1965 to maintain an atomic time scale by counting seconds from crystal oscillators calibrated with reference to the caesium beam standard. In 1968 a commercial caesium standard was added to the group of crystals and its greater long term stability has resulted in an appreciable improvement in the uniformity of this atomic time scale. These scales have been compared to those of other countries including the U.S. National Bureau of Standards at Boulder and the U.S. Naval Observatory at Washington, and over the years have agreed within a few tens of μs. The comparisons by radio methods have been supplemented by flying clock experiments on a regular basis provided by the courtesy of U.S. private and official authorities. Observations on a number of radio stations, on the Dominion Observatory standards, on Loran-C, were made regularly and the published values made available on request to other interested users. The emphasis on time keeping to measure frequency is certain to increase.

In the area of standardization of both electrical quantities and of frequency and time, much international cooperation is needed and secured through organizations such as CPEM, URSI, CCIR as well as the BIPM. The CPEM (international Conference on Precision Electromagnetic Measurements) was held in Boulder, June 1968; the CCIR (International Radio Consultative Committee) Boulder, July 1968, Geneva September 1969 and New Delhi January 1970, were all attended by staff members with advantage to the work of the laboratory. The URSI (International Union of Radio Science) General Assembly was held in Ottawa August 1969, and many visitors from abroad availed themselves of the opportunity to visit the Electricity Section.

For many years there has been close collaboration between NRC and the Dominion Observatory to maintain Canada's Time Service. With the definition of the physical second in terms of the properties of the caesium atom and with the necessity of maintaining a time scale in order to yield exact comparisons of frequency the desirability of closer ties is apparent. On the grounds of efficiency, economy, and improved performance by consolidation of equipment and personnel, the Time Laboratory of the Dominion Observatory and the frequency and time group of the Electricity Section were merged on 1 April 1970 to form a new Time and Frequency Section of the Physics Division.

Heat and Solid State Physics

This section is responsible for the maintenance of the International Practical Temperature Scale in Canada and for thermometer calibrations on this scale; for other, auxiliary, temperature standards; and for development work in various aspects of temperature measurement. A considerable amount of time is devoted to instrumentation, mainly thermometric or electrical, at very high levels of precision; this includes a substantial effort to implement partial or full computer control of a number of experiments and calibration procedures.

Temperature Standards

The International Practical Temperature Scale of 1948 (IPTS-48) was superseded by the IPTS-68 in 1969. The new scale extends to lower temperatures than its predecessor, this extension involving the use of five additional fixed-temperature points. Significant differences in numerical values of temperature have been introduced over much of the range that was covered by the IPTS-48, consequent upon the revised numerical values assigned to many of the fixed points of the scale and changes in the methods used to calculate values of temperature between these points.

Work is continuing on the establishment of the limits of accuracy that can be obtained at some of the higher (Cu and Au freezing) and lower (O_2 and A boiling and triple) points.

The NRC gas themometer previously used to establish the relation between thermodynamic temperatures and the IPTS-48 in the range 90 K to 273 K is being modified so as to relate thermodynamic temperatures to the IPTS-68 between 0°C and 450°C. A considerable amount of work is being done, in co-operation with other national standards laboratories, on the establishment of new, internationally-accepted emf-temperature tables for various types of noble metal thermocouples.

Calibration

Recent major changes in calibration procedures have been the installation of a salt bath, and the use of a computer for writing calibration reports. The former has raised the upper limits of our calibration baths from about 350°C to about 550°C. The latter has approximately doubled our output per man hour for the bulk of our calibration work, provided reports in a more useful and easily varied format, and very substantially reduced the incidence of undetected errors.

Instrumentation

A current major project is oceanographic instrumentation; this is being partly financed by other Government agencies. A group of instruments reading one or more of the quantities temperature, depth, and salinity has been developed. These employ dc or square wave ac measuring circuits with meter, x-y recorder or digital readout. The various designs are now commercially manufactured (but with a continuing development program operating in the section) and are in operation in various water bodies, from Arctic to tropical, and both salt and fresh.

A very considerable effort has been devoted for the last eighteen months to the concept of computer-controlled experiments. A number of experiments in the Division are sufficiently repetitive in nature to make this form of operation attractive, provided that the unusually high precision that is characteristic of measurements in a standards laboratory can be achieved by this means. Experimental complexities are frequently such as to demand a computer of at least moderate power and versatility. The high cost (circa $100,000) of such a computer requires that, to be economically feasible, it control a number of experiments simultaneously. A Hewlett-Packard 216B is now on line as the central control unit for this purpose; a concentrated investigation and development of automated measurement techniques has, we hope, solved the problem of accuracy. The first two or three experiments (e.g. thermal expansion measurements and standard cell intercomparisons) should be running by the middle of 1970.

High Temperature Physics

The high temperature group is concerned with the determination and interpretation of the normal transport properties (thermal conductivity, electrical resistivity and thermoelectric power) of solid metals in their characteristic high-temperature ranges. Both from an experimental and theoretical point of view, the thermal conductivity presents the greatest challenge, and it is this property on which most effort has been concentrated.

Several systems for the simultaneous measurement of the transport properties from 40 to 1500 K have been developed; these systems have been thoroughly tested and inter-compared, and consistently yield results with an error less than 1% in the thermal conductivity and thermoelectric power, and 0.1% in the electrical resistivity.

Using these systems, the properties of the noble metals, and of Pd, Pt, Fe and Co have been measured, and currently work is in progress on Ni and on the alkali metals. The high precision of our systems has permitted us to see effects previously buried in experimental scatter: thus for instance the results show a minimum in the thermal conductivity of Na, and evidence for electron-electron scattering in the noble metals.

In interpreting the results, the chief difficulties are of a quantitative nature. Qualitatively, one can "explain" most, if not all, of the features found experi-

mentally in the thermal conductivities of the various metals. However, all attempts at calculating this property have failed miserably, for reasons not altogether clear, as calculations of the electrical resistivity appear to be quite satisfactory. We are hoping that a detailed comparison of our forthcoming results on the alkali metals with those already obtained on the noble metals will help to decide whether the computational difficulties originate in the electrodynamics, or the electron-phonon interaction.

Instrumental Optics

A large proportion of the work of this section concerns the performance of photographic systems, with practical applications chiefly in aerial survey photography. Contributions are made to optical and photographic standards. Special optical instruments are designed and assistance is provided within Government and to industry on a wide variety of optical problems.

Calibration of Aerial Survey Cameras

The new camera calibrator is being improved in versatility and accuracy for both routine calibrations and research purposes. Routine calibration in the photographic infra-red has been provided by modifications in the illuminating systems of the calibrator and of the associated interferometer used in flattening photographic plates. Other modifications permit calibration of cameras up to 60 cm focal length. For research, modifications to permit calibration at a greatly increased number of image positions and in narrow wavelength bands are designed and are in preparation.

In the two year period, 89 camera tests, 128 magazine tests and 111 port glass tests were performed for 21 Canadian organizations.

Performance of Aerial Survey Cameras

A study of dimensional changes in aerial film in a survey camera led to recommendations of procedures for minimizing these distortions.

An extensive investigation of the resolution of four films in an aerial survey camera under various controlled conditions provided data for the optimum choice of film, aperture, shutter speed, and processing to suit operating conditions.

Apparatus was prepared for a series of tests to study vibration occurring in aerial survey cameras in practical use, with a view to assessing its effect on image sharpness. The first few tests of the series have been carried out.

Optical Design & Consulting

Assistance continues to other NRC laboratories, other Government departments, and industry on a wide variety of optical problems. Acquisition of a computer program for lens design considerably increased the scope of this service and will make possible the complete design of even complex systems where justified by special needs.

Industrial Standards

Chairman and secretariat were provided to the CSA Committee on Survey Photography, the CSA Committee on Eye Protection, and its technical subcommittee.

A light source was designed for sensitometry of aerial photographic films from 350 nm to 920 nm, and incorporated in a published standard.

An extensive study of the literature on eye hazards from optical radiation, and tests on a number of eye protective materials supported development and publication of standards on eye protectors.

Laser and Plasma Physics

The group is primarily concerned with applications of the laser in atomic and plasma physics and the development of lasers suitable for this work.

Studies of θ and z-Pinch Plasmas by Means of Light Scattering

The laser as a light source of unexceeded coherent brightness and power has acquired a key role for the diagnostics of plasmas, especially high temperature plasmas. Lasers have made it possible to observe the very weak light scattered from the density fluctuations in plasmas and these fluctuations play an important role in describing the microscopic and macroscopic behaviour of plasmas.

One of the main objectives of the group is the development of light scattering methods and their application to the investigation of high temperature plasmas. The latter are produced in a 100 K-joule θ-pinch, a machine which transfers energy into the plasma in the manner of an inductive heating device, and in a z-pinch which is a linear high current discharge between two electrodes.

In the past it was shown that the asymmetrical scattering spectra from ion acoustic waves in a θ-pinch could not be interpreted by assuming a shifted Maxwellian velocity distribution as proposed by other workers, but must result from some other mechanism associated with the differences in the Landau damping of oppositely propagating ion waves.

Since Landau damping depends on the first derivatives of the velocity distributions of electrons and ions, the work has been concentrated on an accurate measurement of the Thomson scattering spectrum which represents a direct mapping of the electron velocity distribution. In a first attempt, a reduction in the standard deviation of the mean value of each

spectral point to about 5% was achieved. The resulting spectra indicated, in fact, a deviation from a Maxwellian distribution of velocities at electron velocities corresponding to the phase velocities of ion acoustic waves. The accuracy of measurements, however, did not permit quantitative conclusions to be drawn. Since there was indicated also another quite unexpected deviation from a Maxwellian distribution in the wing of the distribution and a blue shift of the whole spectrum, it was decided to extend the accuracy of the measurements still further.

After considerable effort the standard deviation of the mean value of each spectral point is now of the order of 1% and the spectral resolution is also improved. A first investigation of the red wing of the spectrum confirms the lack of electrons at velocities corresponding to the phase velocity of ion acoustic waves. Moreover, it confirms the deviation from a Maxwellian in the red wing of the spectrum and shows its nature more clearly. In addition, a well pronounced peak at the plasma frequency became visible with higher spectral resolution. This peak might be the equivalent in a high temperature plasma of that which has been observed in a stationary arc plasma elsewhere. As with the foregoing deviations, this peak also cannot be explained as yet and more measurements with varying plasma parameters are required.

In another effort, a method was developed to determine electron density distributions in a plasma by a single shot measurement, without encountering the disadvantage of other widely used methods which accumulate greatest errors for the highly interesting central portions of the plasma. For this purpose, use is made of scattering from electron plasma waves, the frequency of which is closely associated with the electron density, so that an electron density distribution in the plasma is mapped as a frequency distribution of the scattering intensity. Also, here an unexpected and unexplained feature was observed, i.e., a narrow line distinctly separated from the superposition of plasma frequency satellites. This observation also requires further investigation.

Through the use of a mesh-conductor-z-pinch device, the scattering due to waves propagating in different directions could be studied. Thus, the influence of the longitudinal discharge current on the excitation of waves could be observed and, by a comparison with existing theories, it could be shown that at least this kind of plasma can be described reasonably well by a Maxwellian velocity distribution for ions and a shifted Maxwellian for the electrons.

Laser Produced Plasmas

Earlier investigations of laser-produced plasmas have been continued and a detailed study of the development of sparks, produced by focusing a Q-switched ruby laser beam in various gases, has been carried out by means of ultra high speed Schlieren photography. In this experiment a mode-locked neodymium: glass laser was used as a light source for the Schlieren system, thus yielding exposure times of a few picoseconds with an interval of ~ 5 nanoseconds between exposures. In addition to this application, as a very rapid stroboscopic light source, mode-locked lasers have permitted the extension of gas breakdown studies to the picosecond region. Using such a laser, with an electro-optical shutter to select only one pulse from its output, single picosecond pulses having energies as high as 1 joule have been obtained after amplification. A preliminary experiment on gas breakdown has been carried out and the pressure dependence of the breakdown threshold in nitrogen and argon was measured between 500 and 6000 torr. Although the results obtained showed that the pressure dependence in the picosecond region was similar to that observed previously with nanosecond pulses, further studies of the resulting plasmas are planned.

A passively Q-switched ruby laser, operating in a single axial and transverse mode, was also set up for the investigation of laser breakdown in gases and the experiments involving this device have yielded a number of unexpected effects. Of these the most interesting are the appearance of filamentary regions, having transverse dimensions considerably smaller than the focal volume when the spark is observed at 90° by means of scattered laser light, and a large amount of scattered laser radiation emerging in the forward direction. Both of these observations are compatible with the occurrence of some type of self-focusing effect and to confirm this interpretation more detailed investigations are being carried out at the present time.

With the development of high-power transverse excitation CO_2 lasers, by scientists at the Defence Research Establishment, Valcartier, it has become possible to extend the gas breakdown studies to a wavelength of 10.6 microns. Such a CO_2 laser has been constructed and preliminary studies of the sparks produced when the output is focused by a short focal length germanium lens are being carried out.

Several requirements for an extremely fast high-voltage switch, with minimum delay time and jitter, resulted in the successful development of a pressurized laser-triggered spark gap. This device, which has been triggered by laser pulses containing energies as low as 10 microjoules, has been used as the switch in a transmission line pulse generator, and multikilovolt, rectangular pulses, with durations ranging from less than one nanosecond to 20 nanoseconds, have been produced. A potentially important application for this device, which is being investigated, is the generation of gating and deflection voltage pulses for electro-optical image converter cameras.

Mechanics

The Mechanics Section is responsible for the maintenance of those Canadian primary standards of measurement which are essentially of a mechanical nature, and for their dissemination both as the legal

units for the country, and for their use in precision measurements in industry and research. Therefore it is essential to ensure that measurement facilities, which will meet the present and anticipated Canadian requirements, exist in the laboratory and that these are not inferior to internationally accepted concepts of such facilities. Of necessity this objective demands research and the development of techniques, systems and devices for making the required measurements.

Legal Metrology

The departmental reference metric weights of the Department of Consumer and Corporate Affairs were certified in conformance with the requirement of the 1951 Weights and Measures Act that these items be reverified by the National Research Council of Canada at least once every five years. Three sets of weights were calibrated under this program. One particular set covering the range 20 kilogrammes to 1 milligramme has been systematically certified since 1938. After an initial loss of mass on each weight those of 1 kg and greater have exhibited a stability of better than 2 parts in 10^6 since 1949. Reflecting the changing requirements of Canadian industry the same Government department has extended its services into the field of pressure measurement and the Mechanics Section has accepted the responsibility of certifying its pressure transfer standards, two of which were tested.

Precision Measurements

The overall operations of the section can be grouped into the three categories of mass, length and derived measures.

Mass

Work centres around the maintenance of reliable national reference standards of mass calibrated in terms of the International Kilogramme and the extension of multiples and submultiples of that mass. The primary equipment for the work is the laboratory's highly specialized and specifically designed 1 kg balance having an accuracy of the order of 1 or 2 parts in 10^9. To improve the availability of this reference service to Canadian industry and research organizations the Section has studied some of the newly designed electronic balances and these, with their automatic readout capabilities, are being adapted to the uses of the Section.

Length

The laboratory makes measurements for legal, survey and industrial purposes. All the work is either very precise or of an unusual nature. The commonplace type of measurement can, in general, be handled by industrial "quality control laboratories" and it is their reference items which are handled by the Mechanics Section.

The increasing use by industry of numerically controlled two and three coordinate machine tools and measuring machines has resulted in demands for the verification of proving fixtures and test components to establish the precision of such machines. This type of work will be more readily and easily accomplished and actual measuring operations made on the machines themselves when two specially designed and portable interferometers are fully operational. Both instruments are based on the helium-neon laser and are basically the retroreflector modification of the classical Michelson interferometer. The output of the fringe count, from a bi-directional counter, is corrected for environmental effects to give the traversed displacement of the reflector. An instantaneous readout can be taken without interrupting the traversing rate. The simplest of the two interferometers has a resolution of 0.3 μm at a maximum translation rate of 0.1 m/s while the other is fitted with an electronic interpolator with a sensitivity of 0.001 μm.

Most length measurements necessitate the displacement of some component or device over a strictly defined path, most usually a straight line. To enable straightness measurements to be made rapidly, an automatic alignment telescope and target system has been fabricated and this system produces a continuous alignment (or straightness) error record at the rate of 0.4 m/minute with an accuracy of the order of 0.6 μm.

The increasing use of long steel measuring tapes by heavy industry has inevitably required that additional and unusual lengths, other than the traditional surveyor's lengths of 50 ft, 100 links, 50 metres, etc., be calibrated on these items. For many applications, such as the strapping of large cylindrical components, the tape should be verified at every graduation. Whilst not approaching this ideal state, but to increase the versatility of the normal tape calibration service, an instrument has been developed which can be used to verify sub-intervals as small as 10 cm throughout the length of suitably marked and graduated tapes. The system, which has just become operational, still requires the conventional type of calibration of the overall length of the tape. The actual subdivision is then made to an accuracy of about 25 μm with the tape ribbon running at a maximum rate of 1.2 m/s photoelectric detectors which sense the positions of the graduation lines.

Derived Measures

The basic measures of length and mass naturally extend themselves into the derived measures of force, pressure density and similar magnitudes.

As a result of aerospace and other industrial demands, a pressure measuring laboratory has been assembled to cover the pressure range 0 to 40 atmospheres. Most of the work is confined to the region 0 to 2 atmospheres. Techniques for the accurate determination of the cross sectional areas of piston-cylinder assemblies have been devised and interferometric methods are being married to a conventional mercury manometer which is the basic instrument of the laboratory. The work on the effective area of piston-cylinder assemblies has led to agreement of the

order of 15 parts in 10^6 between pressure measurements (up to 2 atmospheres) made by the mercury manometer technique and the dead-weight piston gauge.

Improvements have been made in the calibrations of the angle generating components being used by industry. Our ability in this field was, in the recent past, improved from the order of 0.1 sec of arc to 0.03 sec of arc. Presently some commercially available devices are guaranteed to be accurate to 0.1 sec of arc. Preliminary tests indicate that in actual fact these units have a reproducibility of the order of 0.01 sec and the laboratory has now assembled the equipment and perfected the techniques to realize a calibration system having a probable error of the order of 0.01 sec.

Metal Physics

The Metal Physics group concentrates on the study of the physical properties of metals in its broadest sense, dealing with both mechanical properties and electronic structure. It is clear now that an understanding of the behaviour of metals requires knowledge in both these fields. Since the problems encountered are quite complicated, in order to gain a fundamental understanding, the materials studied are generally of the simplest type, and hence the section has developed sophisticated techniques necessary to produce quite perfect single crystals of the purest metals and alloys with extremely well controlled compositions.

The current experimental and theoretical work in the group can be roughly divided into the following sections: Fermi surface studies of pure metals and dilute alloys; electronic structure of intermetallic compounds and ordered alloys; calorimetry; semimetal semiconductor transitions; mechanical properties of face-centred cubic metals and dilute alloys both in tension and fatigue; mechanical properties of hexagonal metals.

The theoretical work involves calculations of band structure and Fermi surfaces and the effective interatomic binding potential for simple metals, with special emphasis on its application to the structure of dislocations and point defects.

The deformation of pure Cu crystals is being studied both in tension and in fatigue in order to determine the dominant mechanism responsible for hardening and to develop an understanding of the substructure during the deformation. In fatigue it has been shown that very small changes in the strain amplitude result in catastrophic change in the deformation mechanism, which may be the precursor to the persistent slip mode of deformation and lead eventually to fatigue failure. The continued study of pure metals and dilute alloys has produced more evidence that in f.c.c. metals the dominant obstacle to slip is the dislocation forest.

It has been suggested that the hardening in h.c.p. metals results from an interaction between parallel dislocations and twinning. To throw more light on this problem, the deformation of Cd crystals is being studied. Introduction of forest (intersecting) dislocations by predeforming on the pyramidal system raises the flow stress on the basal system by nearly two orders of magnitude; the obstacles introduced by pyramidal glide are longer ranged than those produced by basal slip alone, but after a short recovery at room temperature the plastic properties become identical.

Another unresolved problem under study is the nature of hardening produced by impurities in f.c.c. metals. According to present theories it should not persist to room temperature. In the simplest case of hardening at low temperature, a surprising effect which was dicovered here some years ago is still not understood; crystals soften with decreasing temperature below about 45°K. The effect has been found to be general and should be important in understanding the mechanism of impurity-dislocation interactions.

The dislocation core structure is believed to dominate the low temperature properties of all b.c.c. metals. However, the methods of linear anisotropic continuum elasticity are incapable of giving information on short range details of defects, because of the discrete nature of the crystal lattice and the finite range of atomic forces. Using many body theory techniques the treatment of conduction electrons has been improved to the point where a reliable interatomic potential for simple metals can be derived from a fundamental basis. So far, attention has been focussed on Na where both static and dynamic properties of the perfect crystal in both the b.c.c. and h.c.p. phases are well reproduced. The potential is used in calculating the structure and properties of the dislocation core. The calculations have shown that the differences in properties of the h.c.p. and b.c.c. phases result from core structure differences. The thermodynamic properties of point and line defects are now being studied in Na.

Fermi surface (F.s.) investigations by the de Haas-van Alphen (dHvA) effect continue to form an important part of the electronic structure studies of the group. Two large superconducting solenoids are employed in this work, one giving 55kG with very high homogeneity, used in the pure metal and dilute alloy studies, and the other giving 100kG with somewhat lower homogeneity, used for the measurements in ordered alloys and intermetallic compounds. Through the use of automatic data acquisition and computer analysis techniques it has been possible to make high precision measurements not only of dHvA frequencies but also, where necessary, of the variation of signal amplitude with magnetic field. These data give details both of F.s. cross-section and of electron-scattering on the orbit concerned.

Papers published and submitted for publication in the last two years have reported studies of alloying and electron scattering in copper, alloys of silver and gold, the F.s. of ruthenium, magnetic interaction effect in silver, some new results on β'-brass, and the F.s. of PtSn. There have also been several related theoretical papers, and a new paper on the effect of alloying on the F.s. and electron scattering in Cu is being prepared for publication. Some work on F.s. and electron scattering in the homovalent noble metal alloys (Ag-Au, Ag-Cu, Au-Cu), in collaboration with Dr. M. Springford at the University of Sussex, is also nearing completion. In addition the earlier investigations of the effect of hydrostatic pressure on Fermi surfaces with a study of the behaviour of K, Rb and Cs are being continued. In the field of intermetallic compounds the F.s. of AuGa, which has an unusual orthorhombic crystal structure, is currently being studied both experimentally and theoretically.

In recent experiments it was possible to show that very dilute transition metal impurities in copper cause a modification of the magnetic energy levels of the conduction electrons which has a dramatic effect on the amplitude of dHvA signals. The study of these effects should give useful information about the nature of the interaction between conduction electron spins and localised magnetic moments, and of the mechanism whereby the Kondo condensation screens out these moments. The first observations were made in dilute alloys of Cr in Cu, but since then similar effects have been found in dilute solutions of Fe and Mn.

The 100kG magnet has also been used recently in a study of the possible formation of an 'excitonic insulator' during the semimetal-semiconductor transition in single crystal Bi-Sb alloys at low temperatures. Some inconclusive evidence was found for this effect, which should occur when the band overlap is precisely zero.

Calorimetry of a variety of metals is being continued with new automatic data acquisition equipment. Current investigations are particularly concerned with the noble metals. Pure Ag and Au have been investigated in order to improve our knowledge of their specific heats in the region above 20°K and studies of Ag-Au and Cu-Au alloys, both in ordered and disordered forms, have been carried out with particular emphasis on the influence of the electric quadrapole moment of the nuclei. In addition studies have been made of very dilute alloys containing transition metals which give anomalously large contributions to the electronic specific heat at low temperature and of alkali metals in the melting region.

Our earlier interest in superconductive switching devices has been revived. These devices, of which the current versions use thermal rather than magnetic switching, are used for low-noise circuit selection in a liquid helium bath.

Optical Physics

The program in optical physics is designed to provide primary length calibration services of the highest accuracy to Canadian industry and science, to improve or discover new interferometric length measurement techniques, and to cooperate with other national laboratories in improving the primary length standard to meet demands for higher accuracy. To these ends research has been carried out on improved techniques for the precise absolute calibration of end gauges and scales, on the development and application of several types of laser sources, on the design and production techniques of optical thin films, and on the optical properties of a number of semiconductors and semimetals.

The Section routinely calibrates for outside users a variety of length standards up to one metre, directly in terms of standard wavelengths. Most of the equipment for this work was, of necessity, built in the laboratory, and further development of the equipment to keep abreast of advancing techniques is a continuing task. Considerable progress has been made, for example, in applying fringe counting with a stabilized laser source and automatic data acquisition to the calibration of the one millimetre rulings on a metre scale, a task which would have been prohibitively tedious by earlier methods. An infrared CO_2 laser developed in the laboratory is being applied to the measurement of geodetic tapes in order to extend interferometric accuracies to lengths considerably longer than one metre.

Preliminary measurements have been carried out recently on the symmetry of the Kr^{86} radiation which forms the present primary length standard, and of the wavelengths emitted by a microwave discharge krypton lamp. However, the major part of the effort devoted to radiation sources has been directed to gas lasers. Methods have become available in the past two years for stabilizing the laser wavelength to a reference which has the possibility of being considerably more accurate than the present krypton standard.

One method developed in the Section stabilizes the red He-Ne laser wavelength to a saturated absorption line of iodine at very low pressure. The wavelength has been measured to $1:10^8$, but the inherent accuracy of the method appears to be several orders of magnitude better. This point is to be investigated through the intercomparison of two I_2 controlled lasers. The method has also allowed a detailed study of the quadrupole hyperfine structure of the iodine lines at a resolving power not previously attainable in the visible part of the spectrum. The detailed physics of the behaviour of this type of laser with a saturable absorber in the cavity is being studied.

He-Ne lasers operating at 3.4 μm in the infrared can be stabilized against a saturated absorption line of methane. Two methane-stabilized lasers have been

set up in the laboratory and they produce the same wavelength to better than $1:10^{10}$. Precise absolute wavelength measurement of these sources is being planned.

Interferometric techniques were extended further into the infrared to obtain preliminary values of the wavelengths at 10 μm produced by a stable CO_2 laser developed in the Section. This done, the CO_2 laser can now be used for length calibration of intermediate accuracy.

The computing and practical construction methods of the thin film program have developed to the stage where a considerable array of achievements can be reported. A reflector has been developed on which the reflectance at a single desired wavelength can be set by adjusting two independent calibrated controls; a patent on this device is expected to be issued in the near future. Filters have been made to adjust the response of photodetectors very close to each of the three CIE curves representing the standard observer. These thin film filters are much less complicated, and more efficient than the absorbing glass filters previously used for this purpose. Filters for changing the apparent colour temperature of a source have been made, as has an efficient intracavity wavelength selector for use in ion lasers and a variety of special beam splitters, interference polarizers and reflectors to meet special needs. The computer program required for the design of filters has been sold to a number of commercial producers.

The optical properties of a variety of semiconductors and semimetals, including As, Se, Te, HgS, ZnS, ZnTe, and proustite have been studied for possible use in electrooptic modulators, nonlinear mixing of laser radiations and solid state lasers. Most of the materials have been prepared in the laboratory in crystal or thin film form and new crystal forms of these materials have been produced by novel techniques.

In addition to the calibration and thin film construction mentioned above, members of the Section have provided advice to numerous outside firms and agencies, particularly on interferometric methods and gas lasers.

Photogrammetric Research Section

The work of the Section continued to be concentrated on fundamental research, theoretical investigations of analytical and analog photogrammetric methods and instrumental development.

Fundamental and Theoretical Investigation

The research pursued in the field of off-line analytical photogrammetric methods during the past two years was mostly concerned with the development of a method for the external adjustment of internally adjusted blocks. A program for planimetric adjustment of internally adjusted blocks has been completed. A similar method for height adjustment of strips has been programmed. Several variants of analytical aerial triangulation for large-scale mapping were evaluated.

In on-line computational photogrammetry, procedures for the exterior orientation of models under near-real time conditions and different hardware configurations of photogrammetric on-line systems continued to be studied. As a consequence of this investigation, a new operator's control panel was designed and built into the NRC analytical plotter system. The coordination of supervisory and application programs was made compatible with the new panel. An analysis of limiting factors in real-time processing of photogrammetric data is being conducted. An investigation of sources of errors and their reduction in incremental digital servo-links and the determination of peak and average errors of rotating incremental encoders was performed. The overlapping image-plane fields from a pair of separated two-lens imaging channels sharing the same coherent source of allumination were theoretically examined for possible use in image correlation.

The investigation of methods for correcting of image deformation based upon réseau photography has been continued, and a number of test photographs have been processed and analyzed. An interlaboratory film stability test involving three photogrammetric laboratories was initiated, and the necessary computer programs for corresponding data processing have been coded. A theoretical investigation was conducted on the feasibility of a coding camera for automatic deconvolution of planar film deformations.

A study on the accuracy of orthophotos has been extended to include a comparison of the differentially rectified images with conventionally rectified images. Investigation into the metric aspects of stereo orthophotos and their evaluation as the basis for plotting and photo-interpretation is under way. A series of investigations on large-scale mapping involving line-drawn maps, orthophotos and stereo orthophotos of selected rural and urban areas is under way.

Some selected geodetic problems were studied concerning the atmospheric refraction theory and its application to photogrammetry, electronic distance measurement and satellite geodesy.

Instrumental Developments

Two instrumental developments based on orthophoto and stereo-orthophoto techniques are the Orthocartograph (design at an advanced stage) and the Stereocompiler (prototype completed in the past year). The combination of these two instruments represent a new approach to photogrammetric data processing with far reaching consequences on cartographic procedures.

Component and circuit changes were made on the NRC analytical plotter system's computer to achieve

Stereocompiler—a new photogrammetric instrument for plotting, measuring and photointerpretation, based on stereo-orthophoto techniques.

more reliability when working in a dedicated mode. The further development of this system is oriented toward the creation of a flexible research tool for the study of advanced on-line data processing concepts. Dual optical path was introduced into the system to accommodate a future correlating and monitoring device.

"Lincap II", an improved version of a high precision length measuring device based on the measurement of capacitance ratio, was completed and the initial tests are being conducted. The design of "Circap", a high precision angle measuring device based on the same principle, is completed and the construction of a prototype initiated.

Concerning automation in photogrammetry, several projects were active. Tied to the orthophoto technique are the automatic drop-dot contouring device, the automatic shading device and a device for automatic stereo-orthophoto generation. For use in real-time computational photogrammetry, theoretical investigations and feasibility experiments were initiated for a new solid-state image correlator based on a small area matrix of phototransistors.

Other miscellaneous instrumental developments are under way such as the ultrasonic brain scanner and the point transfer device. Based on earlier clinical tests, further improvements are being made on the ultrasonic brain scanner. A set of air-cushioned frames was designed, built and adapted to a point transfer device.

Non-cartographic Photogrammetry

Active projects in the past two years range from applications of photogrammetric methods to particle dynamics, geology, highway barrier testing to photogrammetric recording of buildings of historical interest. The most significant experiments being conducted are the applications of analytical photogrammetric methods to medicine in general (e.g. recording of phenomena occurring in the interior of the eye) and to medical rehabilitation in particular.

Radiation Optics

The main activities of this section have been in the fields of photometry and color vision.

Photometry

The development of photometric standards has continued and improved calibration techniques have evolved particularly in spectroradiometric measurements on tungsten-halogen as well as fluorescent lamps. The unique spectroradiometer developed in this laboratory has become the basic instrument for

making the measurements that are required to establish suitable working standards of spectral radiance and spectral irradiance in the wavelength region 300 to 830 nanometers.

The development of equipment for accurate determinations of spectral response characteristics of physical detectors of radiant energy, in wavelength region 300 to 830 nm, has also reached the point where measurements can be made on a routine basis for many kinds of detector.

A numerical analysis program has been developed which is being used to design optical filter combinations to modify the spectral response characteristics of physical detectors to certain given standard characteristics required in photoelectric photometry and colorimetry.

Good progress is also being made in the development of reflectance standards for spectrophotometry in terms of absolute reflectance units.

Color Vision

The exploration of the ability of the human eye to assess magnitudes of color differences is continuing by making use of a seven-field visual colorimeter. Preliminary results obtained indicate that improved mathematical models of predicting color-difference judgments by the average observer may be possible. A Riemannian type metric of color-perception space is likely to exist.

A large visual color-matching apparatus has been constructed to assist in the further exploration of the basic color-matching properties of the human eye and other psychophysical aspects of color vision. An extensive program in this area is about to commence.

Spectroscopy

The work in the spectroscopy laboratory is concerned with the study of the spectra and the structures of atoms and simple molecules.

Atomic Beam Laboratory

It has been found that the Zeeman effect of the hyperfine structures of Pr^{141} in the ground and metastable states $^4I_{9/2}$, $^4I_{11/2}$, $^4I_{13/2}$ and $^4I_{15/2}$ cannot be accounted for on the assumption that each J level is unperturbed by any other level to a significant extent. The extraction of a value for the nuclear magnetic moment from the $\mu_I \cdot H_{External}$ term of the usual hyperfine structure Hamiltonian has thereby been made more difficult. At the same time the problem has been made more interesting.

The lifetime of the 2^1S_0 metastable state of helium has been measured by a time-of-flight method and has been found to be about twice as great as the theoretically estimated value.

A study of the zero-field level crossing of the 6^3P_1 state of Hg has shown that if a transverse RF magnetic field is applied to the sample, the fluorescence is modulated at harmonics of the driving field frequency. The level crossing signal is broadened by the RF field indicating that the Landé g-factor is RF field dependent, in quantitative agreement with theory.

Larger Molecules

Considerable effort has been devoted to the detailed interpretation of the visible spectrum of glyoxal ($C_2H_2O_2$) and its isotopic derivatives. Approximately 30,000 rotational transitions have been identified. Rotational and vibrational constants have been determined, and the molecule shown to have a *trans*-structure in its ground(^1A_g) and excited (^1A_u) states. Vibrational frequencies for the ^3A_u excited state have been obtained from magnetic rotation studies. The emission induced in glyoxal by an argon ion laser has been shown to contain fluorescence bands (^1A_u-^1A_g), phosphorescence bands (^3A_u-^1A_g) and further bands belonging to a new band system. Rotational analysis of one of these bands in absorption has shown that it is produced by the *cis*-isomer.

The vibrational analysis of the near ultraviolet spectrum of pyridine has shown that the molecule is slightly nonplanar in the excited state. One of the out-of-plane bending frequencies decreases considerably on excitation, from 404 cm^{-1} to $\sim$60 cm^{-1}, and shows a very anharmonic behaviour in the excited state.

The flash photolysis of cyclopentadiene (C_6H_5) produces a transient spectrum thought to be caused by the cyclopentadienyl free radical, C_5H_5. Proof of this assignment has been obtained by preparing all the possible deuterated derivatives viz. cyclopentadienyl-d_1, -1,2-d_2, -1,3-d_2, -1,2,3-d_3, -1,2,4-d_3, -d_4 and -d_5. The isotope shifts and number of deuterated derivatives obtained show that the five hydrogen atoms are equivalent.

Microwave Spectroscopy

The techniques of microwave double resonance are being used for systematic studies of collision-induced rotational transitions. For the first time, definite experimental evidence has been obtained for the existence of selection rules for collision-induced transitions. Collisions of NH_3 with many atoms and molecules (He, A, Xe, H_2, HD, D_2, para-H_2, O_2, N_2, CH_4, SF_6) have been studied. It has been found that the selection rules depend much on the collision partner; they indicate the symmetry of the dominant intermolecular interaction. Recently an infrared laser has been successfully used for the pumping. Since the deviation from the Boltzmann distribution established by the laser is much larger than that by microwave pumping, one may expect this method to be more powerful in detailed studies. Work in the immediate future will concentrate on collision phenomena of astrophysical interest, such as NH_3-H_2 and CH_2O-H_2 collisions.

In the last two years considerable effort has been devoted to the development of a microwave spectrometer of extremely high resolution. Using the Lamb-dip saturated absorption technique a width of 1.6 kHz has been obtained for the OCS J = 2←1 line at 36 GHz. Hyperfine doubling (due to the protons) of the K=1 lines of CH_3CN has been observed. The saturation dip technique will make possible many investigations of hyperfine structure of lines within the normal Doppler width of the lines.

The range of operation of normal spectrometers has been extended from the previous 8 GHz to 40 GHz region to 410 GHz by the construction of a millimeter wave spectrometer. A detailed study of HSSH, HSSD and DSSD has been completed, and other measurements have been made on HCN, HCP, CHF_3 and CH_3Br. The spectrometer is very suitable for free radical studies, and a search for the BF spectrum has begun.

Small Molecules

Studies of various small molecules have been carried out in the infrared, the visible, ultraviolet and vacuum ultraviolet regions. The infrared spectrum of NH_3 containing the N^{15} isotope has been studied and the inversion frequencies of this molecule have been obtained. In the visible and ultraviolet regions, work on the radicals HNF, PH_2 and CCO has been completed and a good deal of information about the structures of these radicals in the ground and first excited states has been obtained. Considerable work has been carried out on the absorption and emission spectra of simple molecular ions. Absorption of familiar ions such as N_2^+, CO^+, CO_2^+, N_2O^+ and CS_2^+ has been found. One rather unexpected ion whose absorption and emission spectrum was obtained was C_2^-, which gives rise to a very simple spectrum in the visible region. A spectrum of the H_2S^+ ion has been obtained in emission but has not yet been analysed. Some interesting spectra of the diatomic molecular ions NH^+, SiH^+, CS^+ and CN^+ have been obtained and analysed, yielding rotational and vibrational constants as well as information about the electronic structure. Other diatomic molecules that have been studied are AlH, BeH, CH, C_2, BF, NO, SO, Mg_2, Br_2 and I_2. An interesting addition to the list of diatomic molecules is argon hydride, for which a very simple and characteristic spectrum was observed in the red which corresponds to a transition between two excited states of this molecule, the ground state being unstable. Considerable work has been done on the vacuum ultraviolet spectra of H_2, HD, D_2, CN, OH and Si_2. An extensive table of the constants of all known diatomic molecules is being prepared.

Theoretical Studies

The theoretical formalism conventionally used to extract the geometry and force constants of a triatomic molecule from its observed spectrum has been modified. This modification is principally necessary in order to avoid the multitude of questionable parameters that occur in the conventional treatment when we make use of data from states in which the bending vibration is highly excited. Application to experimental results on a bent excited state of HCN is encouraging.

The effect of the breakdown of the Born-Oppenheimer approximation on the determination of B_e and ω_e for a diatomic molecule has been determined. Also, an advance in the understanding of the group theory of a linear molecule has been made. Work on the calculation of the energy levels of Rydberg states of diatomic molecules has been completed and the quantum defects of the Rydberg states of the NO molecule have all been interpreted.

Theoretical Physics

The problem of the stationary points of a function or a functional, subject to equality constraints, leads to what are called abnormal problems when the differentials of some of the constraint equations vanish automatically on the domain defined by the constraints. The discussion of these questions in the literature is not satisfactory. An attempt (using the methods of topology) has been made to get a better treatment. The work is not yet completed. The above mathematical work is needed to deal with some controversial questions on supplementary conditions and the spontaneous breakdown of symmetry in quantum mechanics.

Dr. S. Shanmugadhasan will in future be associated with work in our Cosmic Rays & High Energy Particle Physics group.

X-Rays and Nuclear Radiations

The activities of the Section are mainly guided by requirements of Canadian users for standards and calibrations in the field of X-rays, γ-rays (up to 50 MeV), neutrons and radioactivity. Users of our facilities include hospitals, suppliers of radioactive materials, universities, agencies concerned with radiation protection and other laboratories at NRC. To improve accuracy and uniformity of measurements, comparisons are carried out regularly with major national laboratories throughout the world. Staff members serve on various committees and panels of international organizations, notably the International Bureau of Weights and Measures.

New programs, aimed at increasing the energy range of our standards and at improving methods of measurement have been initiated with the installation

of two nuclear accelerators in 1968. These machines are: (1) An electron linear accelerator, capable of delivering electron pulses of durations from 3 ns to 3.3 μs within an energy range of 3–55 MeV; (2) a positive ion generator (Van de Graaff), producing a continuous beam of protons with energies up to 4 MeV or of doubly charged helium ions up to 8 MeV.

In addition to the standards work the machines are eminently suited to carry out fundamental research in nuclear physics and radiation chemistry. Here, quite informally, a very fruitful co-operation with university scientists, principally from Toronto and Trent has developed. This collaboration on various nuclear research projects enables our staff to maintain the close contact with advances in nuclear physics which is necessary in order to make advances in X-ray and nuclear radiation standards.

Dosimetry of X- and γ-radiation

For X-rays generated at potentials from 10 kv to 250 kv two free air chambers now allow the direct measurement of exposure (in roentgens) and serve as standards to calibrate instruments. For Co-60 γ-radiation, graphite cavity chambers continue to be used. However, hospitals and industries have increasingly been using higher energies of radiation (up to tens of MeV). Since above a few MeV, exposure measurements become less certain, it is necessary to rely on absorbed dose, which can be measured more accurately and, in any case, is the more relevant quantity. A calorimeter is now being constructed which will be placed into the electron beam of the linac, or into the bremsstrahlung spectrum. A chemical dosimetry system which measures absorbed dose directly (except for a constant for the chemical reaction) will be completed shortly.

Radioactivity

Present methods for absolute disintegration rate determinations yield accuracies of about 0.1% for complex β-decay, electron capture (E.C.)-γ decay and pure β-decay, and of about 1% for pure E.C. decay. These methods have now been extended to techniques for decay scheme studies in conjunction with calibrated Ge(Li) and Si(Li) detectors. Measurements of conversion coefficients for transitions following decay in Cd-109, Hg-203, Ce-139 and of the E.C./β^+ ratio in Na-22 and Sc-44 decay are in progress. These efforts will be supplemented by an iron-free β-spectrometer which is now being updated to include β-γ coincidence measurements and to improve counting efficiency, with a position-sensitive solid state detector. Also, in the hope of improving solid state detectors for the study of low energy electrons, surface effects in silicon were studied. Here a new kind of negative resistance effect was observed, the quantitative analysis of which is now being pursued further.

Neutron Physics

Since applications of standard neutron sources require a good knowledge of their spectra, the neutron energy distributions from ^{241}Am-Be and ^{210}Po-Li sources were determined. After the acquisition of the positive ion generator, such measurements were extended by systematically studying the differential cross section for the Be(α,n) reaction with a stilbene proton-recoil spectrometer. Not only was insight gained into the reaction mechanism, but it was also possible to calculate the spectrum for a corresponding radioactive neutron source more accurately than it can be measured directly.

Nuclear Structure Studies by Alpha Capture Reactions

Ge(Li) detectors are being used to study nuclear levels in ^{19}F, ^{20}Ne and ^{44}Ti by the γ-rays emitted following resonant capture of alpha particles. Doppler shift measurements sometimes allowed the lifetime of the level to be determined, and angular distribution measurements in certain cases led to unambiguous spin assignments for the nuclear levels. The zero spin of the α-particle simplifies interpretation.

Photoneutron Studies and the Bremsstrahlung Spectrum from the Linac

Excited states in ^{13}N and neutron branching ratios have been studied by neutron time of flight on the ^{14}N(γ,n) reaction using the bremsstrahlung spectrum from the linac. Other light nuclei such as ^{19}F, ^{23}Na, and ^{32}P will be the next target nuclei to be investigated. The bremsstrahlung spectrum was determined by measuring the neutron energies from the photodisintegration of deuterium. Such a "spectrometer" will lend itself to total absorption measurements and experiments will begin shortly.

Radiation Chemistry

Most of the efforts are concentrated on pulse radiolysis experiments using the linac. Liquid samples were irradiated with a single electron burst and the formation and decay of transient species were followed photometrically at known wavelengths. Investigated at present are: penicillamine, liquid hydrocarbons and peptides. Other projects include steady state radiolysis of methane and vacuum photolysis of organic liquids.

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RADIO AND ELECTRICAL ENGINEERING DIVISION AND ASTROPHYSICS BRANCH

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Approximately equal effort is devoted to basic and to applied research in the Division's program. Astronomy figures prominently on the basic side, both through research activities by staff astronomers and through the operation of the Algonquin Radio Observatory which is maintained as a national radio observatory. The transfer to the Division, on April 1, 1970, of the optical and radio astronomers of the Department of Energy, Mines and Resources will consolidate the program and provide a strong focal point for astronomical research in Canada.

The applied research effort covers a wide range, with emphasis on the application of computer techniques to a variety of fields. Prominent in this program is the establishment of a central computer facility which will be used cooperatively with federal and provincial agencies in the evaluation of terminal equipment and software used in computer-aided learn-

ing systems. Other applied projects include the application of microwaves to industrial drying processes; the development of precision electrical instruments and standards, and research and development in the field of biomedical engineering.

Antenna Engineering

Antenna Development

The development of antennas and transmission components for specific applications has continued to occupy much of the effort in the Section. A variety of radio telescope feed systems were designed and constructed for use at the Algonquin Radio Observatory, and include a series of variably polarized microwave feeds for use on the 150-foot radio telescope. Work undertaken for the Canadian Forces (RCN) has related primarily to the development and evaluation of shipboard HF and UHF antennas and has been carried out using the pattern range maintained for scale model testing of radiating systems.

Other antenna development projects have included a two-dimensional strip-line array for use with a radar altimeter, a shipboard antenna for the reception of signals from a weather satellite, a log-periodic dipole array in which the high and low-frequency elements are interlaced in order to reduce the length of the antenna, and a reactively loaded annular slot antenna for dual-band operation in the VHF range.

Extensive antenna test facilities are maintained, which are available to outside users as well as to NRC personnel.

Electromagnetic Theory

The theoretical program is broadly based and involves the development of mathematical techniques and their application to problems in electromagnetic and antenna theory. Geometrical diffraction theory concepts have been used to revise Schelkunoff's expression for the gain of a pyramidal horn, to include first-order aperture-throat interaction of H-polarized horn fields. The study of singularities of solutions to differential equations has continued, with application to two-dimensional boundary value problems. Other studies have included the determination of the reflection from an interface between an anisotropic plasma and air in a parallel-plate waveguide; an examination of the admittance of a center-fed thick linear antenna; a historical survey of the general antenna admittance problem; the solution for diffraction of a plane wave by a unidirectionally conducting strip; the determination of the cutoff wavelength and field distribution for TE propagation in a rectangular waveguide with double ridges placed symmetrically about the waveguide axis; and the properties of a large uniform array above a stratified medium.

Industrial Applications of Microwaves

The effort on the industrial applications of microwaves has been steadily increasing, with emphasis on moisture sensing and drying. Developments in this area have included a ridged-waveguide glue-line dryer used in the manufacture of business forms; a multiply ridged waveguide for use in processing wieners and sausages; an instrument for monitoring content at the output of a continuous butter making machine; a microwave dryer for 9.5-inch wide photographic film; a 'single-sided' moisture sensor for use on continuous web materials and a 'single-sided' applicator for drying of such materials. The entire program in microwave heating is being carried out in close cooperation with industry, through Canadian Patents and Developments Ltd., and shows considerable promise in many areas of industrial processing and manufacturing.

Shape and Orientation of Precipitation Particles

In a cooperative program with the Information Science Section, a 16.5-GHz radar has been developed as a research tool to study the mean shape and orientation of precipitation particles through polarization observations. Means are provided for precise control of the state of polarization, and preliminary measurements show that it is common to observe a high percentage of precipitation particles (typically 70%) with a preferred orientation.

Data Systems

All rocket payload engineering projects and the satellite data encoder project were completed early in 1968. The activities of the Section are now entirely in the field of information processing. Approximately half our effort is devoted to data handling systems and half to man-machine communication problems.

Data Systems

The computer controlled data acquisition and control system for the radio telescope at the Algonquin Radio Observatory is nearing completion. The data acquisition portion of the system has been implemented and is in constant use by astronomers. Study of the control portion of the system is in its final stage. Technical assessment of the problems is well advanced.

The degree of control system sophistication depends on astronomers' needs as well as technical factors and consultation with these users is required.

A computer controlled FM telemetry tape digitizing system is being designed and assembled on behalf of the Space Research Facilities Branch for scientists participating in the Canadian Rocket Research program. Data on analog telemetry tapes from rocket

flights is automatically digitized and rerecorded on digital magnetic tape for computer processing.

A number of small specialized data recording systems have been developed for research groups in the Division. These systems were designed for experiments with unusual requirements. A good illustration of the type of system is an auroral intensity recording system which operates unattended at a remote site for periods of two months. Other systems are used in auroral, luminescence, and precipitation studies. These systems contain tape recorders, (magnetic tape recording of data), analog-to-digital converters and appropriate clocking and control hardware to implement automatic recording of data in a format appropriate for subsequent computer processing.

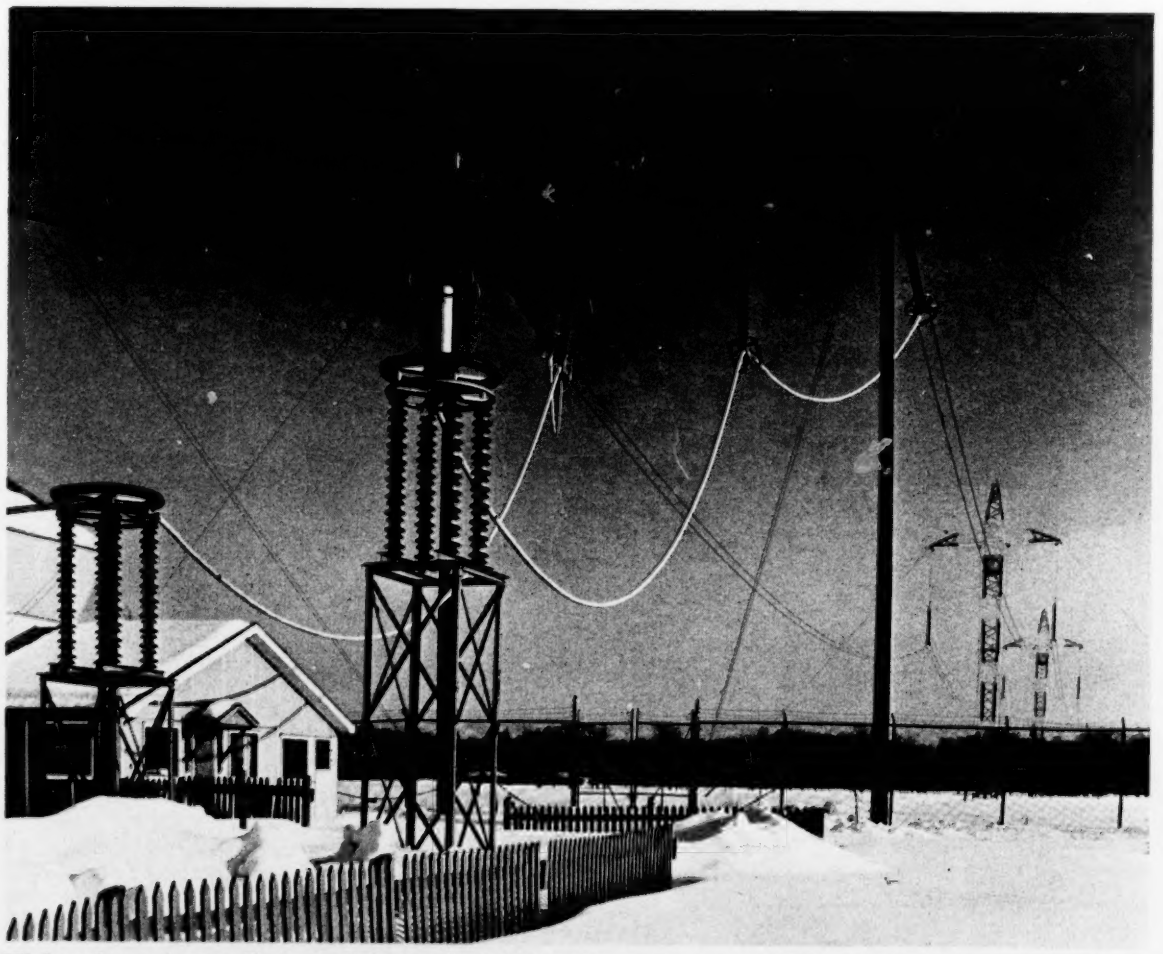
Man-Machine Communications

System engineering and software development for a computer-controlled graphical display facility has been a major activity during this two-year period. A system consisting of a medium sized computer, a disc drive, magnetic tape transport and paper tape facilities, and a CRT display with vector hardware has been assembled. It is being used primarily for a general study of computer utilization in creative activities.

Specific problems which seem likely to further an understanding of man-computer communication are being studied. These problems, all graphically oriented, are film animation, chemistry research (molecular vibration), musical composition, and network analysis (CPM/PERT). Methods of giving control of computer facilities to creative people, who do not themselves write programs, are being developed in collaboration with these people.

Electronic music activities are centered around serial structure generator work done in collaboration with University of Toronto, and controlled chance studies done in collaboration with McGill University. New electronic music devices, a touch-sensitive keyboard, an improved voltage controlled oscillator, and a system of sinewave oscillators have been developed.

In the man-machine communications field it was found that many researchers were not well acquainted with the work of others. Accordingly, in May 1969, a seminar on Man-Machine Communications was organized and sponsored by the Section. Canadian researchers in university, government, and industry participated.



High voltage dc test lines used for radio interference and corona studies at the radio and electrical engineering field station.

Electrical Engineering

High Voltage

A long term study of the high voltage characteristics of overhead dc transmission lines is proceeding. One of the objectives is to identify the various corona phenomena and their manifestations on full scale lines under various weather conditions. This includes a study of electrostatic fields in presence of the widely dispersed space charges originating from corona at conductors. The second objective is to provide means for predicting the corona loss and radio noise characteristics of proposed long lines. The work has been carried on in close collaboration with electric utilities, universities, and engineering societies.

The study of the behaviour of measuring systems for high voltage impulses has continued to be an important part of the Section's activity. Initially, this work was concentrated on the evaluation of measuring systems for specific types of impulses normally used in testing. However, lately it has been realized that the impulses considered have been ideal types which are not obtained in practice. Such an approach has simplified the study of the measuring systems but has tended to obscure their capabilities for measuring actually occurring impulses. Because of this aspect, the investigation has now been expanded to include the complete impulse generating system and a quite new appreciation of the behaviour of the over-all system is beginning to emerge.

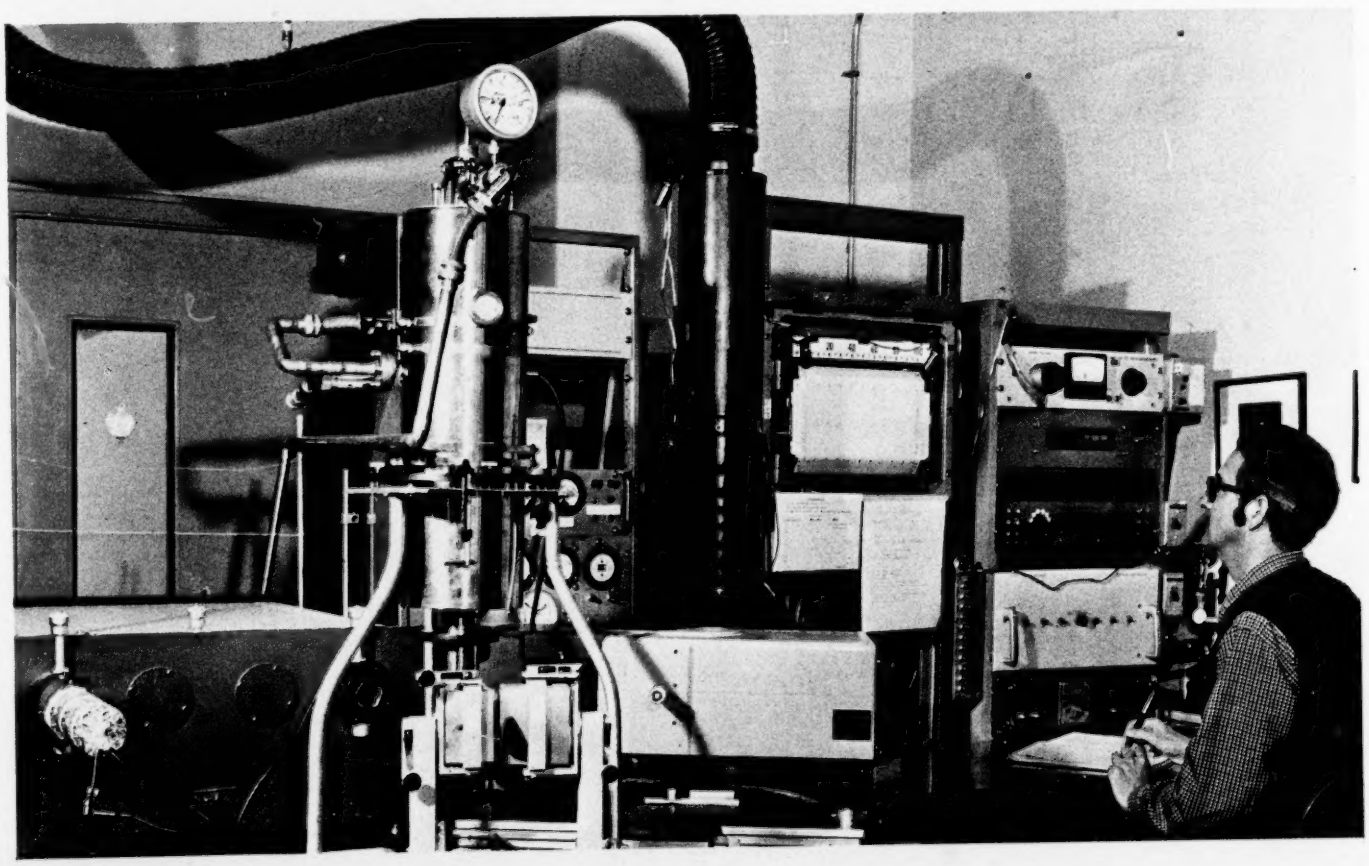
Precision Measurements

New applications of the direct-current comparator have included a seven-dial potentiometer with a linearity of one part in 10^7, and a resistance thermometer bridge capable of resolving 0 to 111 ohm thermometers to one micro-ohm (0.01 milli-Kelvin). The ratio range of the resistance bridge was also extended to 2,000,000 to one, with a maximum current capability of 20,000 amperes. The ratio capability of the current transformer calibration equipment has been extended upwards to 36,000/5 amperes and down to 0.05/5 amperes, and ratio sets have been developed to enable the measurement of ratio errors from one part per million to 11.1%.

Solid State Physics

The study of optical effects arising from the decay of triplet excitons in anthracene has led to an interpretation of the delayed fluorescence in terms of exciton traps. An associated investigation, in which the magnitude and time-dependence of the phosphorescent emission from the crystal is measured, is now under way. It makes possible a direct determination of the triplet exciton population and thus provides important information concerning the fundamental properties of molecular crystals.

Experimental determinations of the Schottky energy of alkali-halide crystals have been refined over



Apparatus used in studies of the fluorescence of solids.

the past few years. By means of conductivity measurements on crystals doped with cationic and anionic impurities, and computer analysis of the results, it is possible to improve the accuracy over that of earlier determinations. The method has been applied to three alkali halides and others will be investigated as time allows.

Work on the phonon structure arising from the presence of molecular impurities in alkali halides is continuing. High resolution measurements at low temperature have made possible very accurate determinations of the spectroscopic constants of molecular anions in these crystals.

Theoretical studies of the energy to form a pair of vacancies in an ionic crystal (Schottky energy) have been recently refined and extended. Both the analytical expressions and the computer calculations involved are very complicated. Final results are expected shortly.

Electron Physics

Physical adsorption isotherms of argon, krypton, and xenon extending from ultrahigh vacuum to vapour pressure have been measured. This range had never previously been covered in a single measurement. The adsorbent was porous silver at 77°K. An analytic expression describing all the data was developed.

Work on the impact of inert gas ions on the surfaces of clean single crystals of tungsten has been extended to helium ions on W (100) and W (110). Two general types of trapping sites were identified, those present initially in the tungsten and those created by the incoming helium ions. The latter type of site could also be produced by bombardment of the crystals with heavy inert gas ions of Ne, Ar, Kr, and Xe. Subsequent bombardment by 250 eV He ions was used to study the damage created by the heavier ions.

An inexpensive high-energy electron diffraction (HEED) apparatus has been constructed in Pyrex glass. A study of the adsorption of hydrogen on single crystals of tungsten (100) and (110) has shown that HEED is as sensitive to surface adsorption as low-energy electron diffraction (LEED). An Auger electron spectrometer of coaxial geometry using no magnetic fields has been constructed and preliminary studies of chemisorption and ion bombardment have been made.

An apparatus for experiments in molecular diffraction under ultrahigh vacuum is being constructed. A pressure of 5×10^{-10} Torr was achieved before installation of the final pumping stage, which was to be a cryosorption pump using porous silver at 4.2°K. The porous silver cryosorption pump has been tested successfully in an auxiliary apparatus.

Variations up to about 20% in the measured sensitivity of Bayard-Alpert gauges were correlated with variations in the Auger ejection yield of the collector. The sensitivity was influenced by chemically adsorbed gases, by sputtering, and by the outgassing of the gauge. Collectors of platinum-clad molybdenum showed the smallest variation. Measurements on the dependence of the sensitivity of Bayard-Alpert gauges as a function of grid-to-filament spacing were correlated with the angular momentum of the electrons about the central axis of the grid; a new gauge design was successfully tested which minimized this angular momentum.

A new principle for pumping gases at low pressures —termed accommodation pumping—has been found. The principle is based on previous work on thermal transpiration.

Multiply charged ions of carbon and oxygen (up to CO^{4+} and O^{6+}) have been observed during electron bombardment of carbon monoxide in a trapped-ion source. Most appearance potentials could be correlated with spectroscopic values. The pressure dependence of multiply charged ion currents for the gases He, Ne, Ar, Kr, and Xe in a trapped-ion source in the pressure range 10^{-9} to 10^{-5} Torr has been measured. A simple theory has been developed which gives reasonable agreement with experiment. Multiply charged ions of Ba (up to Ba^{10+}) and of Cs (up to Cs^{10+}) have also been observed.

Following excitation by a helium-neon laser, fluorescence from rhodamine 6G in ethanol, methanol, and glycerol at wavelengths considerably shorter than the wavelength of the exciting light has been observed. As an aid in studying this phenomenon a grating tuned dye laser has been constructed. A liquid helium cryostat has been built to study the line narrowing of fluorescence under resonant laser excitation. Homogeneous line widths of 0.6 GHz for the zero phonon ruby line ($\lambda = 6935$Å) were measured.

Engineering Design

This Section undertakes work from other sections, and sometimes other divisions, under two main classifications. One of these classifications consists of printed circuit work, illustrations, graphs, and art work to accompany reports, publications, and lectures. This includes displays for conventions such as the 16th General Assembly of the U.R.S.I. held at Carleton University in August 1969. The other classification consists of the design of mechanical or structural items required by scientists for furtherance of their research.

Typical projects include receiver cases and a solar sidereal control gearbox for the 150-foot telescope at the Algonquin Radio Observatory; a vario-illumi-

nator, part of an apparatus for the measurement of luminescence spectra; various aids for the blind including a mechanical punched-card reader; and rocket instrumentation and ejection mechanisms. In addition, the Section has been doing a number of jobs for the Division of Biology, such as an automatic zonal scraper, ultraviolet irradiator, and adjustable Dewar mount.

Since the inclusion in the Division of astronomers from the former Dominion Observatory, the Section has become involved in instrument design related to optical astronomy.

Information Science

Computer-Aided Learning

An experimental computer-aided teaching system was developed and used to improve understanding of the problem as preparation for the development of a more versatile system. Subsequently, a PDP-10 digital computer was purchased to provide the basis of a central research facility for cooperative development and evaluation in this field. The preparation and evaluation of course materials and the evaluation of special terminal devices will be in the hands of educators in cooperating bodies all across the country. System design will be the responsibility of the National Research Council.

Methods of communicating with the computer are being investigated. A touch-sensitive x–y data input device has been developed to facilitate information entry. Employing an ultrasonic surface wave echo-ranging technique on a transparent glass plate, the device can be used as an overlay on a display screen. The user may identify items or positions on the screen by pointing a finger or stylus. Continuous graphical input is also possible. An operational model is nearing completion.

Voice control of a computer is being explored. The present approach depends upon initial storage of the digitized voice characteristics of the operators. These are selectively recalled as required for comparison with control words. This autocorrelation should provide a large useful vocabulary while simplifying the equipment.

A study of fully mechanized information storage and retrieval (including classification, indexing, alerting, and inquiry response) is being made in association with the work on computer-aided learning. The present investigation covers computer analysis of title and text for entry and retrieval operations. A computer-controlled retrieval system for use with tape recorders is being developed. A binary-coded decimal number is recorded at a high audio frequency at the beginning of each statement.

Hardware and software now being developed will permit a small computer to be used as a highly flexible line concentrator coupling several student terminals to the PDP-10 through a single telephone line.

Hybrid Simulation

A technique for simulation of digital control systems has been developed, which uses a simple hybrid arrangement of the conventional elements of an analog computer and the digital elements now usually available as an optional accessory. The method is being applied to simulation of single-rate systems, to those having two or more rates or subsystems, and to those having delays in the loop or non-uniform sampling characteristics.

Thin Films

Stable, fast evaporation of silicon has been achieved using an electron beam gun controlled by the charge scattered from the source material. The experimental arrangement for measurement of the energy distribution of charge in an evaporating material has been operated successfully. Resistance measurements during the initial stages of film growth are being made, leading to an investigation of the effect of an applied electric field upon nucleation and growth. The production of two-element films has been accomplished by the deflection of the electron beam between isolated sources.

Weather Studies

In collaboration with the Antenna Engineering Section, the design and construction of a 16.5-GHz radar for study of polarization properties of precipitation has been completed. Regular observations of rain and snow are made, from which information on the mean particle shape and orientation is derived. In addition, the optimum polarization for maximum precipitation clutter cancellation is obtained.

A 5.8-GHz pulsed Doppler radar, employing a variable velocity notch receiver developed here, has been completed and used to determine the radial velocities and radar reflectivities of precipitation particles. Analysis of a storm can be completed within a few weeks and a number of storms have been investigated. A vertically directed antenna is usually employed for rain studies but a second antenna, variable in both azimuth and elevation, is being used during snow storms to measure wind speeds and gustiness at low angles of elevation. Both these weather programs employ tape records with computer reduction of data.

The weather satellite reception project was terminated after successful shipboard trials with several types of antenna. For the Department of Energy, Mines and Resources, a portable system was developed and many pictures, recorded during the years beginning in 1964, were reproduced to show land features. An analog antenna programmer was developed for the Department of Transport and several telemetry antennas were compared.

Instrument

Radio Frequency Standards

Improvements have been made in existing primary reference standards of radio frequency quantities and new standards for additional quantities have been established.

The accuracy and precision of the standard attenuation measuring system have been improved by the incorporation of a 10-kHz synchronous gate in the IF system of the receiver and a new precision ratio transformer. With these modifications the precision of the system is ±0.002 db in a 10-db measurement.

Development and construction of a fast response calorimeter have been undertaken for the calibration of thermistor mounts in the 8.2 to 12.4 GHz frequency range.

The frequency range of the semiautomatic coaxial impedance measuring system has been extended to cover the range of 1 to 8 GHz. A system for 7 mm coaxial lines is being established. A precision waveguide section has been built, based on a National Bureau of Standards design, to be used as a reference standard of waveguide impedance.

In the areas of attenuation and voltage measurement a precision rotary vane attenuator with an optical readout is under construction.

Medical Electronics

The program of development of biological energy sources for implanted electrical pacemakers has been continued. Several cells with oxygen-depolarized cathode and consumable anode have been successfully implanted in animals for a period of a year. A new method for obtaining the standard 12-lead electrocardiogram has been developed which obviates the need for the lead switch and manually changing the leads.

Cooperation with local hospitals and universities has been continued. The program with Queen's University to improve apparatus and techniques for clinical ultra sound encephalography is meeting with success. A digital system for screening patients which automatically prints the shift of the midline ventricle has been completed.

Development of instrumentation for telemetry of physiological parameters from birds in flight and for monitoring ecological patterns of small rodents was continued.

A program to investigate the means of acquiring and recording very low level neutral signals due to optical and aural stimuli has been started.

The Section is cooperating with various standards agencies in Canada and the United States in the writing of new standards of electrical safety for hospitals.

Aids to the Handicapped

An electronic reader for IBM punched cards, to be used by blind computer programmers has been developed. A number of measuring devices have been modified for use by the blind and some of these are in production. An ultrasonic obstacle detector has been developed and a number of units are being built for extensive field trials.

The group holds an almost unique position in the field of aids to the handicapped and more emphasis is being placed on its role as a source of advice and direction to the various agencies which provide assistance to the handicapped.

Navigational Aids

Remote Control of Model Ships

In a study of the performance of scale-model ships in a manoeuvering basin, carried out in cooperation with the Division of Mechanical Engineering, an attempt was made to use machine recognition of sustained vowel sounds to provide voice control of the ships. The zero crossings of the acoustic waves from several voices were examined for uniqueness, and experimental circuitry was built. The results were not encouraging. There does not seem to be any clear-cut pattern in the zero-crossings of the original pressure wave or its derivatives that is relatively invariant from speaker to speaker and reliable enough to be used.

A user's manual for the latest remote control equipment has been prepared and a report written. This completes the remote control system.

Split-Beam Microwave Beacon

A split-beam microwave beacon was designed to provide guidance for ships in narrow channels during foul weather. The system was tested aboard the MV Radel II, and a manufacturing licence granted to an Ottawa company. Preproduction models of the equipment were tested, and modifications suggested. Further tests of the equipment were carried out to investigate the effects of interference with or by ships' radars, and to minimize the effect of signal reflection from the water surface at short ranges.

Fog-Horn Control

A remotely controlled electric fog-horn, installed at the entrance to the harbour at Sydney, N.S., in 1967, has been improved and up-dated by the use of solid-state circuitry in the control system, and changes in the power generator. A new 5-element yagi antenna was installed, in a mounting that will allow easy removal of ice during the winter months. These changes should greatly increase the reliability of the system.

Meteorological Telemetry

The collecting and recording of meteorological data have been carried on for some years at Rogers Pass, B.C.

A telemetry system designed and built by the National Research Council provides measurements of wind velocity and direction, and air temperature and relative humidity from two mountain peaks.

Over the years the equipment has been gradually converted from the use of tubes to solid state devices and, in addition, improvements have been made to the system to provide lower power requirements, greater circuit simplicity and increased data acquisition.

Hail Radar

The Section continues to support the Alberta Hail Research Studies. The project has advanced to the experimental cloud-seeding stage and additional radar facilities have been added for the control of seeding aircraft and mobile ground sampling units. These include a remote PPI display and elevation counters, equipped for polaroid photography. The transparencies are projected on a map of the surrounding area and FM radio is used in the deployment of vehicles in front of an approaching storm.

The variable polarization equipment was used throughout the 1969 hail season. The recorded data are a measure of the sphericity of the scattering particles and consequently the ice content in a storm core. It is hoped that the technique can be developed and used in hail forecasting.

ASTROPHYSICS BRANCH

J. L. LOCKE, *Chief*

Radio Astronomy

The Branch is responsible for the operation and maintenance of the Algonquin Radio Observatory, a national facility for research in radio astronomy. The 46-meter parabolic telescope, the major instrument of the observatory, is now equipped with a versatile data acquisition system employing a high-speed, on-line digital computer. Broad-band receivers are available for routine observations at wavelengths of 2.8, 4.6 and 9.4 cm. A radiometer for λ 2.2 cm is almost ready for installation and an improved λ 2.8-cm radiometer, employing a nondegenerate parametric amplifier cooled to 20°K, is nearing completion.

The recent discoveries of spectral lines produced by excited hydrogen atoms and a variety of molecules in interstellar space have opened exciting new fields for radio astronomy. To enable Canadian radio astronomers using the 46-meter telescope to participate in these studies, a multichannel spectrometer was developed and has been tested in the laboratory. Initially, the system provides 100-kHz resolution and a total spectrum width of 10 MHz, but higher resolutions are planned. The computer is used to control the acquisition of data and process it for display in real time. When combined with the λ 2.8-cm parametric amplifier, the system should be capable of determining spectral line intensities with an uncertainty of 0.04°K. This particular combination should provide an extremely useful tool for the study of excited hydrogen lines.

In the past two years, the 46-meter telescope has been used on a wide variety of programs by members of the Radio Astronomy Section and astronomers from Canadian universities. Several of these programs involved the extension of the spectra of radio sources to wavelengths shorter than 10 cm. The sources studied include not only sources with classical (nearly linear) spectra but also many sources, being discovered in increasing numbers, which have flat or curved spectra. Position measurements made with the 46-meter telescope have made it possible to identify a number of the latter sources with extragalactic optical objects.

An extensive program of observations of over 100 planetary nebulae has also been carried out. The new information, combined with data at longer wavelengths, will enable physical properties such as the electron temperature, radio opacity, radius, and electron density to be determined for each nebula. Still other observing programs were concerned with the mapping of galactic HII regions.

A program, begun in 1966, of regular monitoring of the radio flux emitted by about 50 sources, suspected of being variable, was continued. One of the sources in this study, the remarkable source VRO 42.22.01 (identified with BL Lac, an optical object of unknown type), was found to vary dramatically in times as short as a few days.

Very long baseline interferometry, a technique first used by Canadian radio astronomers in 1967, was extended to longer baselines in a continuing study of the size and structure of very small radio sources. Telescopes at the Algonquin Radio Observatory; Penticton, B.C.; Prince Albert, Sask.; Ottawa, Ont.; and Jodrell Bank, England, have now been used in various combinations to yield effective resolutions ranging from 0.02 arc sec to about 0.5 arc sec at wavelengths near 400 MHz. In all, about 60 sources (primarily quasars) have been observed, of which 33 have been found to have at least one component whose size is less than 0.5 arc sec.

A long-term program of measurement of the absolute flux densities of Taurus A and Cassiopeia A at microwave frequencies was completed during the year. The final measurements were made at a wavelength of 2.2 cm using the accurately calibrated horn reflector of the observatory.

Other programs which were carried on during this period include the long established daily measurement of the solar radio flux and continuous monitoring of solar bursts at a wavelength of 10 cm. Routine observations of the sun were also made with the 32-element array, which provides a daily scan of the radio sun at λ 10 cm with an east–west resolution of 1.5 arc. sec. Observations of the sun with the 74-MHz polarimeter, which had been carried on for a number of years, were terminated on October 31, 1969.

Upper Atmosphere Research

Meteoritics

On 19 nights during 1968 and 1969, combined meteor observations were carried out at the Springhill Meteor Observatory using radar equipment, multiple spectrographs, an image orthicon tube, and a team of visual observers. Some 100 meteor spectra were also recorded by image orthicon with the cooperation of a group from the Dudley Observatory, Albany, N.Y.

Computer processing of data from the 10-year Springhill radar meteor patrol is now nearly complete. Statistical studies were made to analyze meteor mass distribution and echo heights in the atmosphere. A new determination for the differential mass index was derived for sporadic meteors, and the behaviour of the Leonid meteor shower over the past 12 years was investigated.

Micrometeoroid detectors of seven different types

were flown on nine Black Brant rockets launched from Churchill, Manitoba, to derive information on response characteristics and the statistical reliability of impact detection on rockets.

Reports of some 625 fireballs and other events seen in the sky were filed at the Meteor Centre.

A computer program has been written to assist in the determination of meteoroid orbits, and as an aid in predicting the possible fall area of meteorites. A comprehensive statistical analysis of meteorite-producing orbits is being carried out.

Aurora and Airglow

Ionization in the upper atmosphere, particularly that occurring in and during auroral events, was studied using rocket-borne plasma probes. The probes analyze the electron and ion densities, thermal electron energy distributions, and the ionization structure.

Radar studies of the aurora were made by the continuous operation of VHF auroral radars at Ottawa, Churchill, Thompson, and Great Whale. The network provides continuing statistical data and overlapping observation of radio auroral events from differing aspect angles, to obtain greater resolution in the study of aspect sensitivity and its bearing on the reflection mechanisms of radio waves from aurora.

In the studies of scattering mechanisms for aurora, a physical model has been proposed to relate and to explain the data obtained during a radio aurora event which occurred during the IGY. It is hoped that these studies will make it possible to identify events which cannot be explained in terms of current ideas.

A major effort of 1969 was the construction and use of a spectrometer-photometer experiment on the NASA 1969 Airborne Auroral Expedition, which included over 12 teams of experimenters from the United States, Canada, and Europe, and was based on Fort Churchill. New data were obtained on the variation of the intensities of the different auroral emissions over a wide range of geomagnetic times, latitudes, and conditions of geomagnetic activity, which should provide important information on the type and energy of the particles involved in the excitation of visual aurora.

The dayglow emission spectrum of the 1.58μ emission of the $O_2(^1\Delta_g - {}^3\Sigma_g^-)$ system has been determined. Rocket techniques have been used to measure the height distribution of this emission under various conditions.

The mathematical model, which has been used to simulate the photochemical behaviour of an oxygen-hydrogen atmosphere, has been modified to include the effects of eddy diffusion. The model has been used successfully to predict the behaviour of some of the observed airglow emissions and the measured vertical density profile of various atmospheric constituents.

The two stations, Great Whale (55° 18′ N, 77° 45′ W) and Byrd (80° 01′ S, 119° 30′ W), are close to conjugate points in the general magnetic field of the earth. Auroral all-sky cameras and photoelectric photometers were operated at the two stations during the March–September period in 1968 and 1969 to study conjugate-point phenomena. To continue this study in more detail, it is planned to operate, during the next few years, a chain of photometer stations in the vicinity of Great Whale. As part of the development stage of this program, an automatic photometer for unattended operation has been designed and thoroughly tested.

In cooperation with the Arctic Institute of North America, data were scaled from the 1966 all-sky camera records from Byrd and Great Whale for a computer determination of the position of the Byrd conjugate point. The analysis indicated changes in position of the conjugate point over a range of +2 to –5 degrees of geomagnetic longitude and +1.5 to –0.5 degrees of geomagnetic latitude.

The Auroral Centre collected 107,000 visual auroral reports from 44 meteorological stations of the Department of Transport, from various centres of the Royal Astronomical Society of Canada and from other groups of observers. Synoptic auroral maps for quarter-day intervals were plotted, the southern auroral extents were read and these were transmitted on a monthly basis to World Data Centre A at E.S.S.A. Boulder, Colorado.

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SPACE RESEARCH FACILITIES BRANCH

J. F. AITKEN, *Chief*

In lieu of an Advisory Board, two committees have acted in an advisory capacity to the Space Research Facilities Branch. These are the Joint Range Policy Committee (USA – Canada), and the Associate Committee on Space Research.

The Space Research Facilities Branch (SRFB) is charged with the responsibility for developing and supplying the means by which many of the upper atmosphere and space research programs of Canadian scientists are carried out. Scientists concerned have, in general, been from universities and government agencies. In the summer of 1969 it became apparent that the upper atmosphere research for which NRC is responsible would have to be curtailed for budgetary reasons. In addition, it was decided by the National Aeronautics and Space Administration (NASA), the United States agency with whom we had been cooperating in operating the Churchill Research Range (CRR), that NASA would not continue to support range operations as had been done in the past. It was also mutually agreed between NASA and the NRC that the STADAN station near St. John's, Newfoundland was becoming less important in tracking and acquiring data from satellites. It was, therefore, decided to cease operations at that station on 31 March 1970.

SRFB is continuing as the service agency to make arrangements for an upper atmosphere research program in Canada. It is expected that under the revised budgetary conditions a more efficient operation should result. However, this will mean that some of the less essential elements of the sounding rocket program will be deleted in the future, and that services provided to user scientists at CRR will not be as extensive as they have been.

SRFB is responsible for an expeditionary base for rocket launching at Resolute Bay, NWT. A rather similar site at East Quoddy, Nova Scotia which was established for rocket launches during the eclipse of 7 March, 1970, has been retained for possible use on the occasion of the eclipse of 10 July, 1972. It is possible that other locations in Canada will be used by the NRC for rocket-borne experiments during the 1972 eclipse. The operation of the Great Whale Geophysical Station at Poste-de-la-Baleine, P.Q. continues to be a responsibility of this Branch.

Range Section

The Range Section is responsible for the administration and supervision of all NRC-operated sounding rocket ranges. This includes liaison with foreign government agencies regarding their use of the range facilities. At present, there are three NRC ranges in use: the Churchill Range in Manitoba, the expeditionary range facility at Resolute Bay, NWT and the temporary range at East Quoddy, Nova Scotia.

With responsibility for the administration of the Churchill Research Range, the Range Section was engaged for the last six months of the reporting period in planning the reorganization of the CRR facilities and services made necessary by the announced termination of the USA/Canada Agreement for the joint funding and operation of CRR.

With the termination of the USA/Canada Agreement on 30 June 1970, the Joint Range Policy Committee will cease to exist and full control of the Range will be vested in NRC/SRFB. For the future operation of the Range, the staff will be reduced to approximately one-quarter of its previous level. The launch rate capability will be significantly reduced; however, the Range will retain the capability of handling the same types of rockets and payloads as in the past.

Churchill Research Range

Despite the commencement of staff reductions on 1 January 1970, the Churchill Research Range conducted a vigorous launch program through to the end of March 1970. During the two-year period ending 31 March 1970, 552 rockets and balloons were launched. Of the 472 rockets, 125 were major rockets carrying a wide variety of experiments. As in the past years, balloons ranged in size from 60,000 cubic feet to 10.6 million cubic feet carrying payloads of up to 300 pounds to altitudes of 150,000 feet.

One of the most exciting and productive launch programs conducted at the Range occurred on 2, 3 and 4 November 1969, when 36 sounding rockets were launched in a 52-hour period into a Polar Cap Absorption event. Planning for this program commenced in September 1968, two additional twin boom launchers being installed to handle the large concentration of rockets.

Prior to the announcement of the termination of the US/Canada Agreement, a number of major improvements to range facilities were made. These included the addition of a telemetry acquisition aid to the ANFPQ-11 radars; installation of domes over the radar antennas as a protection from weather; consolidation of telemetry at the launch site with the addition of facilities for predetection recording. An IBM 1800 computer was leased for impact prediction, radar data reduction and certain supply functions.

Improvements to the launch facility included the addition of an auroral launcher which could launch sounding rockets in cold weather without the use of

cumbersome heat shields, and a modification to the Nike launcher building which permits personnel to work in a shirt-sleeved environment.

An outstation was added at the North Knife site to provide better triangulation for auroral and other height finding work and a runway was built to enable small fixed-wing aircraft to service this site. A narrow beam riometer was installed at the Auroral Observatory. A German real time telemetry station was installed, for the purpose of acquiring scientific data from German research satellites. Personnel from the CRR were trained on site and in Germany to operate and maintain command and recording instrumentation located at the Auroral Observatory.

Among the space research groups which used the range facilities were representatives of Canada, United States of America, Germany, United Kingdom, and Sweden.

Resolute Bay

Four expeditions to Resolute Bay were undertaken during the period of this report. In August of 1968 two Boosted Arcas I rockets with payloads designed to measure D region density profiles in the polar cap ionosphere were launched for Goddard Space Flight Center (NASA). Two Black Brant III rockets carrying NRC experiments to obtain information on the background radiation from space were launched in the following October.

A year later, in October 1969, a Boosted Arcas II was launched for Goddard Space Flight Center under quiet geophysical conditions. This was closely followed by the firing of four Black Brant IIIB rockets for NRC. The first two were instrumented to measure galactic X-ray sources and the others to study the emission and plasma properties of high latitude aurora.

East Quoddy, Nova Scotia

NRC fired four Black Brant III rockets from the temporary rocket launching site at East Quoddy during the solar eclipse of 7 March 1970. These were instrumented to make complementary measurements of D region ionization and of the sun's radiation in the X-ray and Lyman alpha segments of the spectrum.

Research Support Section

This Section assists in implementing the upper atmosphere research program approved by the Associate Committee on Space Research and works very closely with the Scientific Evaluation Panel of that Committee.

In general, the Section is a service organization which arranges for experiments to be incorporated into rocket payloads, along with appropriate housekeeping equipment, rocket-borne telemetry, power supplies and mechanical devices. It also supplies the rockets, documentation and vehicle support at the launch site. This work is done almost entirely by contract, and the personnel of the Section are involved in contract administration, program control and providing coordination during launch operations. However, the Section also has the responsibility for ensuring that the engineering involved is adequate and acceptable, which involves general direction and detailed monitoring throughout every project. Section engineers also provide the link between scientist and contractor. Engineering inadequacies and their solution, together with the selection and development of equipment to meet new requirements, are continually under review. Vehicle failures have occurred but corrective action has been taken and no further problems with the present Black Brant rockets are anticipated.

The Section was responsible for siting, setting up and equipping the launch facility at Resolute, NWT, which was handed over to the Range Section in 1968.

In 1969 a total of 24 rocket payloads was completed and launched on 4 Black Brant II, 5 Black Brant IIIA, 4 Black Brant IIIB, 5 Black Brant IVA, 3 Black Brant VB and 3 Boosted ARCAS II vehicles. The 4 Black Brant IIIB rockets, the first in the Canadian program, were launched from Resolute in a very smooth operation mounted from Bristol Aerospace at Winnipeg and lasting just under three weeks from leaving to return.

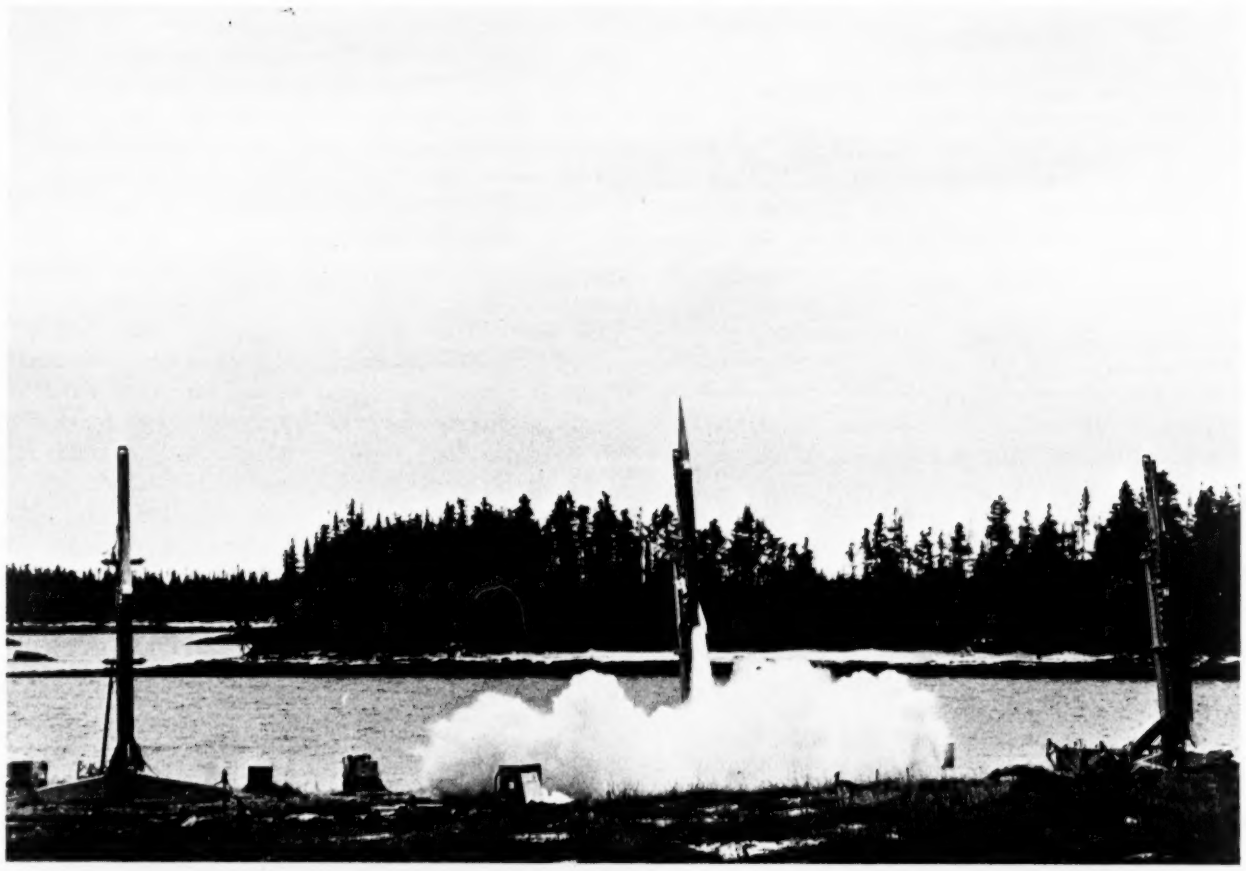
Among important innovations in the Canadian Rocket Program was the successful use of parachutes for the recovery of valuable payloads. Two cases involved the recovery of expensive payload stabilization systems which have been flown for the first time successfully. Two payloads will be reflown in 1970 after refurbishing at a fraction of their original cost.

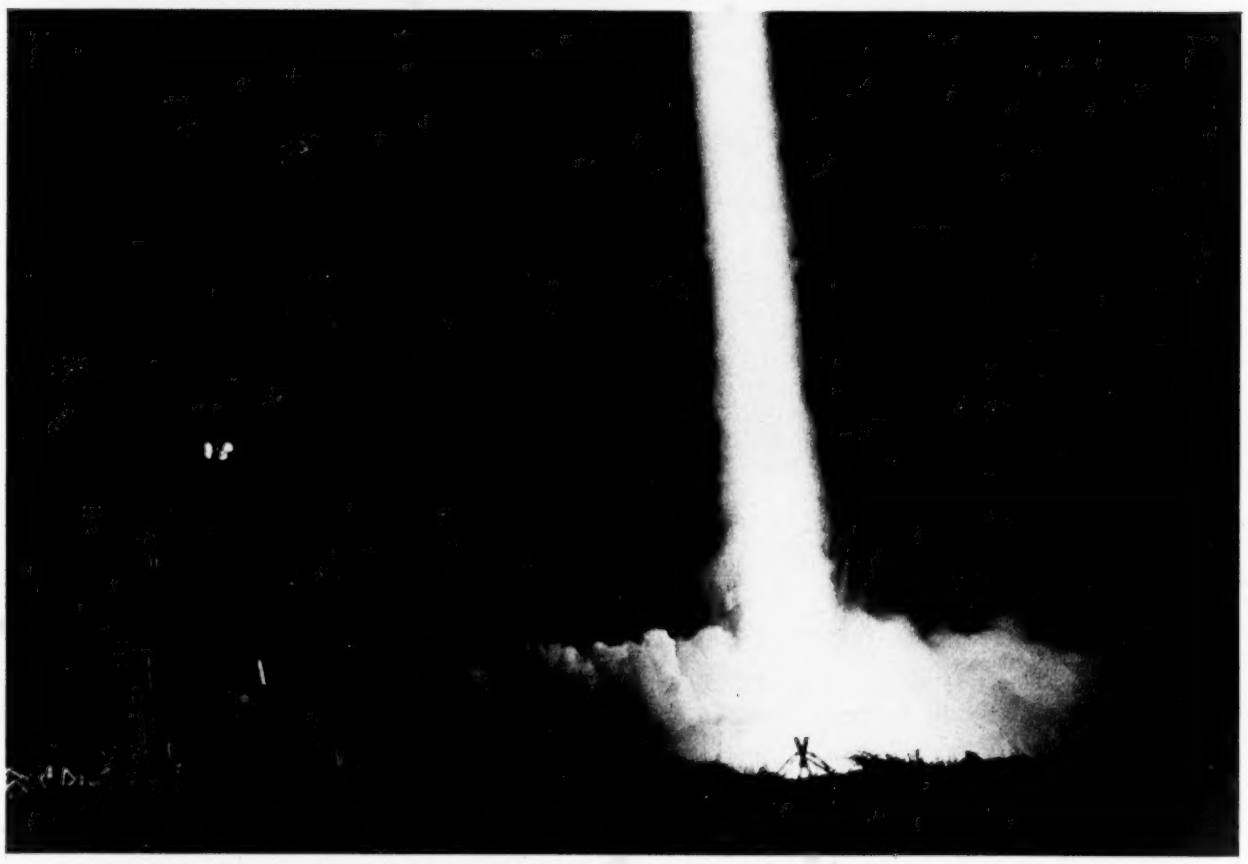
Payload contractors were responsible for the development of several novel electronic devices including timers and DC to DC converters and in the combination of PCM and FM data transmission in a single transmitter. Extensible antennas were utilized in two payloads and in one instance served to despin a Black Brant IVA vehicle. A contractor had also designed a simple despin mechanism applicable to all the 10 inch diameter rockets of the Black Brant series.

To date (31 March 1970) the Section has been responsible for the preparation and launch of 66 rocket vehicles carrying 441 experiments. For a small, low budget, short lead time program, and on a comparative basis internationally, the Canadian success record is excellent.

Data and Reports Section

The information from the experiments carried in research rockets is usually telemetered to the ground during the flight and recorded on magnetic tape. The data from many experiments must be separated and





Launching of two of four rockets fired during total eclipse at East Quoddy, N.S., 7 March 1970. Top: First rocket, launched before eclipse. Bottom: Third rocket launched at total eclipse.

translated into forms more readily usable by the scientists concerned.

Currently, this data reduction is being carried out by the Space Engineering Division of the University of Saskatchewan, under contract to SRFB.

The trajectory information is obtained from the data recorded by the radar or from doppler ranging records. Attitude determination requires the interpretation of magnetometer and signal strength records.

In order that all scientists in universities, government agencies and industry may be kept aware of the research rocket program and its preliminary results, brief reports on all rockets fired under the auspices of SRFB are written as soon as the material can be assembled.

Minitrack Station

Until March 1, 1970, SRFB operated a Satellite Tracking and Data Acquisition Network (STADAN) Station about twelve miles north of St. John's, Newfoundland. This station formed part of the NASA/ Goddard Space Flight Center's STADAN and was operated by contractors for the National Research Council of Canada as a Canadian contribution to cooperative space research with the United States.

The work of the station included interferometer measurements on satellites passing near the station to obtain precise position data, the recording of telemetry signals from satellites and the transmission of commands to satellites. In addition, when weather conditions permitted, photographs were taken of flashing or reflecting satellites against the star background.

Due to a change in the NASA requirements it was mutually agreed that the station should be closed and network operation ceased on 27 February 1970.

Great Whale Geophysical Station

At Poste-de-la-Baleine, P.Q., at the southeast corner of Hudson Bay, the Great Whale Geophysical Station, originally built and staffed by NRC's Division of Pure Physics for the International Geophysical Year, is used by many different Canadian and American experimenters. Many of the experiments started during the IGY still continue to provide valuable data. This station with its staff of three is now the administrative responsibility of SRFB.

Experiments include auroral photography with all-sky cameras, photometry on five different wavelengths and the operation of an auroral radar for the Radio and Electrical Engineering Division. For the Defence Research Board, an 80 kHz transmission from Ottawa is monitored for propagation studies.

Recordings of VLF noise are made for Stanford University and both VLF noise and ionospheric absorption are measured for Environmental Science Service Laboratory of the National Bureau of Standards at Boulder. The data obtained is coordinated with similar material from the Byrd Station in Antarctica which is at the geomagnetic conjugate point to Great Whale.

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SRFB 026 Black Brant rocket AEF-II-118 launched at Churchill Research Range 28 January 1969–June 1969.
SRFB 027 Black Brant rocket AMF-II-117 launched at Churchill Research Range 18 February 1969–July 1969.
SRFB 028 Black Brant rocket AAD-IV-16 launched at Churchill Research Range 6 March 1969–August 1969.
SRFB 029 Black Brant rocket AAF-VB-22 launched at Churchill Research Range 10 March 1969–August 1969.
SRFB 030 Black Brant rockets AAF-III-37 and AAF-III-38 launched at Churchill Research Range 28 and 29 March 1969–September 1969.
SRFB 031 Black Brant rocket ADB-VB-23 launched at Churchill Research Range 31 March 1969–September 1969.
SRFB 032 Boosted ARCAS II rockets AMM-BA-01, 02 and 03 launched at Churchill Research Range April 1969–November 1969.
SRFB 033 Black Brant rockets AHF-IV-14 and 15 launched at Churchill Research Range May 1969–October 1969.
SRFB 034 Black Brant Rockets AAD-II-122 and 123 launched at Churchill Research Range September 1969 –December 1969.
SRFB 035 Black Brant Rockets AKF-IIIB-50 and 51 launched at Resolute October 1969–January 1970.
SRFB 036 Space and Upper Atmosphere Research in Canada—Balloons, Rockets and Satellites—1969–January 1970.
SRFB 036F Recherches en Haute Atmosphère et dans L'espace au Canada—Ballons, Fusées-Sondes et Satellites 1969–January 1970.
SRFB 037 Bibliography—Scientific Papers Resulting from the Canadian Upper Atmosphere Research Program 1965–1969–January 1970.
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SRFB 010 Black Brant rocket AAF-II-108 launched at Churchill Research Range January 1968–April 1968.
SRFB 011 Black Brant rocket ADD-VB-11 launched at Churchill Research Range January 1968–May 1968.
SRFB 012 Black Brant rocket ADD-II-109 launched at Churchill Research Range January 1968–June 1968.
SRFB 013 Black Brant rockets AKD-II-110, 111, 112 and 113 launched at Churchill Research Range in January and April 1968–July 1968.
SRFB 014 Skua II rockets AMD-S2-05, 06, 07 and 08 launched at Churchill Research Range March and April 1968–August 1968.
SRFB 015 Black Brant rockets AAF-VB-04 and 05

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launched at Churchill Research Range March and April 1968–September 1968.

SRFB 016 Black Brant rocket AKF-IV-10 launched at Churchill Research Range 5 April 1968–October 1968.

SRFB 017 Black Brant rocket AMF-II-116 launched at Churchill Research Range 22 April 1968–November 1968.

SRFB 018 Black Brant rocket ADD-VB-18 launched at Churchill Research Range 2 August 1968–December 1968.

SRFB 019 Black Brant rockets AKF-III-39 and AKF-40 launched at Resolute Bay October 1968–January 1969.

SRFB 020 Black Brant rockets ADF-III-29, 31, 32 and 33 launched at Churchill Research Range October and November 1968 and April 1969–July 1969.

SRFB 021 Black Brant rocket AAF-II-125 launched at Churchill Research Range 13 December 1968–March 1969.

SRFB 022 Black Brant rockets AKD-VB-20 and 21 launched at Churchill Research Range December 1968 and March 1969–June 1969.

SRFB 023 Black Brant rocket AAF-IV-17 launched at Churchill Research Range 19 January 1969–June 1969.

SRFB 024 Space and Upper Atmosphere Research in Canada–Balloons, Rockets and Satellites January 1969.

SRFB 024F La Recherche Spatiale et en Haute Atmosphère au Canada–Ballons, Fusées-Sondes et Satellites –January 1969.

SRFB 025 Bibliography–Scientific Papers resulting from the Canadian Upper Atmosphere Research Program 1965–68–February 1969.

THE LONDON OFFICE

W. L. HANEY, *Chief Scientific Liaison Officer*

The National Research Council of Canada has had an office in London since 1941. The role of the London Office is to support the activities of the Council Laboratories, in particular, and to provide liaison and services for other National Research Council activities.

The collection and transmission of scientific and technological information is perhaps the biggest task carried out in the London Office. There is a great amount of scientific and especially technological information generated in Great Britain, much of which is not published in the periodical press and so does not appear in the appropriate abstracts. Because of this, much important information relevant to work in NRC laboratories could remain hidden. To obtain this information, several methods are used. Documents and reports, as distinct from periodic publications, produced by government, university and industrial laboratories, and from research associations, are collected regularly and transmitted to the NRC libraries, the National Science Library and, in some instances, to the individual divisions. This collection of material is possible because of long established links with British organizations engaged in research.

To maintain and to expand these links, numerous visits are made to laboratories and other organisations, and with knowledgeable individuals. Visits are made where the judgement of the liaison officer feels a visit may be profitable. Visits are also made in response to requests by NRC staff. Visits and liaison of this type are often profitable, particularly where mission oriented projects are concerned. In these projects much money and manpower may be involved and, should the problem have been investigated in Great Britain, the savings can be considerable. Both successful and unsuccessful solutions can be helpful.

From time to time requests to attend specialist meetings are received. Several benefits arise from attendance of a liaison officer. Preprints and reports are often available weeks or months in advance of normal distribution and it is sometimes possible to detect important trends. Meetings of this kind are also an important source of personal contacts with experts in various fields.

The provision of services to NRC staff, while travelling, is an important function of the London Office. The office is used as a base for operation, with the usual office facilities available. Use of typing services, telephone, telex, desk space and mailing are typical examples. In addition, itineraries can be made up, travel and hotel accommodation arranged and tickets purchased. In an emergency, financial assistance can be provided. These latter services are especially useful when unexpected changes in a visitor's schedule become necessary. The office is used as a forwarding address and for interviews, or discussions with British colleagues.

Support is available for the administrative activities of NRC. Examples are locating sources of unusual material or equipment, follow-up on purchases, interviewing applicants for employment or academic support, dispatch of goods requiring special handling, arranging for customs clearance of scientific equipment in cooperative experiments in Great Britain. Many requests for information about NRC activities and Canadian science are received from officials and individuals in Great Britain. These are answered, where possible, or referred to the appropriate Canadian agencies in the U.K. or Canada. NRC news releases are distributed to the press and other interested organisations.

The Liaison Officers are attached to the Office of the High Commissioner for Canada, with the diplomatic rank of Counsellor, but the office itself is not at Canada House, nor at Macdonald House where most Canadian Government staff are located. The London Office is located with the Commonwealth Scientific Liaison Offices, in Africa House, 64/78 Kingsway, London, WC2B 6BD (telephone 01 405 9711). The Commonwealth Scientific Liaison Offices are part of the Commonwealth Scientific Committee, a group which fosters scientific cooperation among the Commonwealth nations. The National Research Council is the adhering body for Canada. In order to make liaison between Commonwealth Scientific Liaison Officers more effective, a common location was considered to be necessary.

DIRECTORY OF STAFF

by Divisions and Sections
(Principally Scientific Classifications)

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K. F. TUPPER	O.B.E., B.A.Sc. (Toronto), S.M. (Michigan), D.Sc. (Laval, Western Ont., Sherbrooke), LL.D. (McMaster)	Vice-President (Administration)

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Biophysics		
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L. C. VINING	B.Sc., M.Sc. (Auckland), Ph.D. (Cantab.)	Senior Research Officer
E. G. YOUNG	B.A., M.Sc. (McGill), Ph.D. (Cantab.), D.Sc. (Acadia), LL.D. (Dalhousie), F.R.S.C.	Guest Research Scientist
A. V. EMES	B.Sc., Ph.D. (Leeds)	Postdoctorate Fellow
J. L. C. WRIGHT	B.Sc., Ph.D. (Glasgow)	Postdoctorate Fellow
C.-K. WAT (Miss)	B.S.P., Ph.D. (Brit. Col.)	Postdoctorate Fellow
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L. VODICKA	M.Sc., Ph.D. (Prague)	Postdoctorate Fellow
R. K. BANSAL	B.Sc. (Punjab), M.Sc. (Rajasthan), M.S. (California), Ph.D. (Alta.)	Postdoctorate Fellow
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C. R. MASSON	B.Sc., Ph.D. (Aberdeen)	Principal Research Officer
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P. A. DISTIN	B.Sc., Ph.D. (London)	Postdoctorate Fellow
J. J. GÖTZ	M.Sc., Ph.D. (Prague)	Postdoctorate Fellow
M. HAYER	M.Sc. (Moscow Steel Inst.), Ph.D. (Ostrava)	Postdoctorate Fellow
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ATLANTIC REGIONAL LABORATORY—Concluded

Name	*Degrees*	*Class Title*
Instrumentation		
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Lichenology		
W. S. G. MAASS	Dr.rer.Nat (Tübingen)	Associate Research Officer
Marine Botany (Physiology and Biochemistry)		
J. S. CRAIGIE	B.A., M.A., Ph.D. (Queen's)	Associate Research Officer
M. V. LAYCOCK	B.Sc., Ph.D. (Liverpool)	Assistant Research Officer
R. G. BUGGELN	B.S. (Bucknell), M.S. (Hawaii), Ph.D. (Washington)	Postdoctorate Fellow
Marine Botany (Systematics and Ecology)		
J. L. MCLACHLAN	B.Sc., M.A., Ph.D. (Oregon State)	Associate Research Officer
T. EDELSTEIN (Mrs.)	M.Sc., Ph.D. (Hebrew Univ.)	Associate Research Officer
E. OGATA	B.Sc., Ph.D. (Kyoto)	Associate Research Officer
L. C.-M. CHEN	B.Sc. (Taiwan), M.Sc. (New Bruns.)	Assistant Research Officer
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I. A. N. LUCAS	B.Sc., Ph.D. (Wales)	Postdoctorate Fellow
J. W. MARKHAM	A.B. (Stanford), M.Sc. (Washington), Ph.D. (Brit. Col.)	Postdoctorate Fellow
Marine Laboratory		
A. C. NEISH	B.Sc., M.Sc., Ph.D. (McGill), D.Sc. (Mt. Allison), F.R.S.C.	Director
C. H. FOX	B.S., M.S. (Trinity), Fil.Lic. (Lund), Ph.D. (Clark)	Postdoctorate Fellow
Mass Spectrometry		
W. D. JAMIESON	B.Sc., M.Sc. (Dalhousie), Ph.D. (Cantab.)	Associate Research Officer
Microbiology		
A. TAYLOR	B.Sc., Ph.D. (Manchester)	Senior Research Officer
D. BREWER	B.Sc. (Durham), M.S.A., Ph.D. (Toronto)	Associate Research Officer
S. H. SAFE	B.Sc., M.Sc. (Queen's), D.Phil. (Oxon.)	Associate Research Officer
J. M. DUNCAN	B.Sc., Ph.D. (Glasgow)	Postdoctorate Fellow
W. A. JERRAM	B.Sc., Ph.D. (Melbourne)	Postdoctorate Fellow
D. MEILER (Miss)	M.Sc., Ph.D. (Switzerland)	Postdoctorate Fellow
Physiological Chemistry		
R. A. HEACOCK	B.Sc., Ph.D., D.Sc. (London)	Senior Research Officer
O. HUTZINGER	Ing. (Vienna), M.Sc., Ph.D. (Sask.)	Associate Research Officer
J. E. FORREST (Mrs.)	B.Sc. (Wales)	Junior Research Officer
J. M. GOURLEY	B.Sc., Ph.D. (Nottingham)	Postdoctorate Fellow
R. MARCHELLI (Miss)	Ph.D. (Pavia)	Postdoctorate Fellow
Library		
A. R. TAYLOR (Miss)	B.Sc., Dipl. Sec. Sci. (Acadia), B.L.S. (Toronto)	Librarian

BIOCHEMISTRY LABORATORY

Director's Office		
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C. R. BARON		Administrative Officer
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G. A. ADAMS	B.A. (Queen's), M.Sc. (Western Ont.), Ph.D. (Chicago), F.R.S.C.	Principal Research Officer

BIOCHEMISTRY LABORATORY—Concluded

Name	*Degrees*	*Class Title*
Scientific Research Staff—Concluded		
F. R. AHMED	B.Sc. (Alexandria, Egypt), B.Sc., Ph.D. (Leeds)	Senior Research Officer
G. I. BIRNBAUM	B.Sc., M.A., Ph.D. (Columbia)	Associate Research Officer
C. T. BISHOP	B.Sc., B.A. (Acadia), Ph.D. (McGill)	Assistant Director
J. R. COLVIN	B.S.A. (Sask.), M.Sc. (Alta.), Ph.D. (Wisconsin)	Principal Research Officer
O. E. EDWARDS	B.Sc. (Alta.), M.Sc., Ph.D. (Northwestern), F.R.S.C.	Principal Research Officer
A. W. HANSON	B.A.Sc., M.A. (Toronto), Ph.D. (Manchester)	Senior Research Officer
C. P. HUBER (Mrs.)	B.Sc., M.Sc. (Manitoba), D.Phil. (Oxon.)	Associate Research Officer
H. J. JENNINGS	A.R.I.C. (London), M.Sc., Ph.D. (Queen's)	Assistant Research Officer
B. F. JOHNSON	B.S. (Penn. State), M.A., Ph.D. (UCLA)	Associate Research Officer
H. KAPLAN	B.Sc. (Queen's), Ph.D. (Ottawa)	Assistant Research Officer
C. V. LUSENA	B.Sc., M.Sc., Ph.D. (McGill)	Associate Research Officer
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W. G. MARTIN	B.Sc. (Carleton), M.Sc., Ph.D. (McGill)	Senior Research Officer
A. T. MATHESON	B.A., M.Sc. (Brit. Col.), Ph.D. (Toronto)	Associate Research Officer
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J. M. NEELIN	B.A., Ph.D. (Toronto)	Associate Research Officer
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M. PRZYBYLSKA (Mrs)	B.Sc., Ph.D. (Glasgow)	Senior Research Officer
H. SCHNEIDER	B.Sc. (Sir Geo. Williams), M.Sc. (Western Ont.), Ph.D. (McGill)	Associate Research Officer
I. C. P. SMITH	B.Sc., M.Sc. (Manitoba), Ph.D. (Cantab.)	Associate Research Officer
D. R. WHITAKER	B.Sc. (Manitoba), Ph.D., D.Sc. (London)	Principal Research Officer
R. E. WILLIAMS	B.Sc., Ph.D. (Western Ont.)	Assistant Research Officer
Postdoctorate Fellows		
H. A. AUGUSTYNIAK (Mrs.)	M.Sc. (Moscow), Ph.D. (Poznan)	Postdoctorate Fellow
O. S. BHANOT	B.Sc., M.Sc. (Punjab), D.Phil. (Calcutta)	Postdoctorate Fellow
K. B. BIRNBAUM (Mrs.)	Can. mag., Cand. real. (Oslo), Ph.D. (Glasgow)	Postdoctorate Fellow
B. J. BLACKBURN	B.Sc., M.Sc., Ph.D. (Manitoba)	Postdoctorate Fellow
J. BROWN	B.Sc., Ph.D. (Glasgow)	Postdoctorate Fellow
K. W. BUTLER	B.S.A. (Toronto), Ph.D. (Duke)	Postdoctorate Fellow
G. B. CALLEJA	B.S.A. (The Philippines), M.S. (Ohio State), Ph.D. (Minnesota)	Postdoctorate Fellow
J. L. DOUGLAS	B.Sc. (Brit. Col.), D. Phil. (Sussex)	Postdoctorate Fellow
R. J. FIELDER	B.Sc., Ph.D. (U.C.N.W.)	Postdoctorate Fellow
C. G. FRASER	B.Sc., Ph.D. (Aberdeen)	Postdoctorate Fellow
R. J. GAIT	B.Sc., Ph.D. (Liverpool)	Postdoctorate Fellow
J. GOODCHILD	B.Sc., Ph.D. (Liverpool)	Postdoctorate Fellow
E. M. GOPALAKRISHNA	B.Sc., M.Sc. (Mysore), Ph.D. (Indian Inst. of Tech., Madras)	Postdoctorate Fellow
C. J. C. HSIA	B.S. (Nat'l of Taiwan U.), Ph.D. (Hawaii)	Postdoctorate Fellow
G. B. HAWES	B.Sc., Ph.D. (Univ. Col. of Townsville)	Postdoctorate Fellow

DIVISION OF BIOLOGY

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DIVISION OF BIOLOGY—Continued

Name	*Degrees*	*Class Title*
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R. S. MCCULLOUGH	B.A., M.A. (Toronto), Ph.D. (Iowa)	Associate Research Officer
P. P. F. CLAY	B.Comm. (Manitoba)	Computer Systems Administration
Environmental Biology		
Environmental Physiology		
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J. S. HART	B.A., M.A., Ph.D. (Toronto), F.R.S.C.	Principal Research Officer
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D. W. PETER	B.Agr.Sc., Hon.B.Agr.Sci., Ph.D. (Adelaide)	Postdoctorate Fellow
Pollution		
J. S. HART	B.A., M.A., Ph.D. (Toronto), F.R.S.C.	Principal Research Officer
A. S. W. DEFREITAS	B.Sc., M.Sc. (MacDonald), Ph.D. (Minnesota)	Associate Research Officer
D. C. MORTIMER	B.Sc. (Alta.), M.Sc., Ph.D. (Wisconsin)	Associate Research Officer
C. QUADLING	B.Sc., Ph.D. (London)	Associate Research Officer
R. J. NORSTROM	B.Sc., Ph.D. (Alta.)	Assistant Research Officer
R. K. LATTA	B.Sc. (Manitoba)	Junior Research Officer
G. M. FINDLAY	B.S.A., M.Sc. (Manitoba), Ph.D. (Illinois)	Postdoctorate Fellow
L. C. HO	B.Sc. (Peking), Dipl. (Hong Kong Baptist College), Ph.D. (Hull)	Postdoctorate Fellow
H. W. DE KONING	B.Sc. (McGill), B.Ped, M.Sc., D.Sc. (Montreal)	Postdoctorate Fellow
Food Biology		
Cell Culture		
DYSON ROSE	B.S.A., M.Sc. (Alta.), Ph.D. (Toronto)	Principal Research Officer
S. M. MARTIN	B.S.A. (O.A.C.), M.Sc., Ph.D. (Wisconsin)	Senior Research Officer
I. J. MCDONALD	B.S.A. (Brit. Col.), M.Sc., Ph.D. (Wisconsin)	Senior Research Officer
N. H. TATTRIE	B.Sc. (McGill), M.Sc., Ph.D. (Sask.)	Senior Research Officer
I. VELIKY	Dipl. Eng. Chem., Ph.D. (Bratislava)	Associate Research Officer
M. YAGUCHI	B.Agric. (Tokyo Agric. U.), M.S., Ph.D. (Calif.)	Associate Research Officer
M. MISAWA	B.Agric., D.Agric. (Tokyo)	Postdoctorate Fellow
Food Technology		
C. P. LENTZ	B.S. (Sask.), M.A.Sc. (Toronto)	Senior Research Officer
L. VAN DEN BERG	B.Sc., M.Sc. (Wageningen), M.Sc. (Manitoba)	Senior Research Officer
D. S. CLARK	B.Sc., M.Sc., Ph.D. (McGill)	Senior Research Officer
A. W. KHAN	B.Sc., M.Sc., Ph.D. (Punjab), Ph.D. (Manchester)	Associate Research Officer
T. BURKI	Ingenieur Agronom., Dr. of Technical Science (Swiss Federal Institute of Technology)	Postdoctorate Fellow
A. R. FREY	1st Degree, 2nd Degree, Dipl., Doctorate (ETH)	Postdoctorate Fellow
Radiation Biology		
Radiation Chemistry		
A. S. HOLT	B.Sc. (Rhode Island) Ph.D. (Minnesota)	Senior Research Officer
K. R. LYNN	B.Sc. (Adelaide), Ph.D. (Melbourne)	Associate Research Officer
A. G. SZABO	B.Sc. (Queen's), M.A., Ph.D. (Toronto)	Associate Research Officer
Radiation Dosimetry		
G. C. BUTLER	B.A., Ph.D. (Toronto)	Director
J. G. HOLLINS	B.Sc. (Bristol), Ph.D. (London)	Assistant Research Officer
Radiation Physiology		
J. F. WHITFIELD	B.Sc. (McGill), M.Sc., Ph.D. (Western Ont.)	Senior Research Officer
H. J. MORTON	B.Sc. (Liverpool), M.A. (Toronto), Ph.D. (Ottawa)	Associate Research Officer

DIVISION OF BIOLOGY—Concluded

Name	*Degrees*	*Class Title*
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J. P. MACMANUS	B.Sc. (Dublin), Ph.D. (Lancaster)	Assistant Research Officer
D-P. YANG	B.S.A., M.Sc. (Manitoba), Ph.D. (Illinois)	Postdoctorate Fellow
G. G. LEPPARD	M.A. (Sask.), M.S., M. Phil., Ph.D. (Yale)	Postdoctorate Fellow
E. W. MACAULAY	B.Sc., Ph.D. (Glasgow)	Postdoctorate Fellow
C. MAHENDRAN	B.Sc. (Ceylon), M.Sc. (East Anglia), Ph.D. (London)	Postdoctorate Fellow
R. S. MORROD	B.Sc., Ph.D. (Birmingham)	Postdoctorate Fellow
T. C. MORTON	B.Sc., Ph.D. (Melbourne)	Postdoctorate Fellow
J. M. PATON	B.Sc., Ph.D. (Strathclyde)	Postdoctorate Fellow
D. R. POLLARD	B.Sc., Ph.D. (Glasgow)	Postdoctorate Fellow
T. M. RADHAKRISHNAN	B.Sc., M.A., M.Sc. (Madras), Ph.D. (I.I.Sc., Bangalore)	Postdoctorate Fellow
J. P. SEILER	Lic. phil. nat., Dr. phil.	Postdoctorate Fellow
V. L. SELIGY	B.Sc., M.Sc., Ph.D. (Toronto)	Postdoctorate Fellow
K. R. SHELTON	B.A. (Virginia), Ph.D. (Illinois)	Postdoctorate Fellow
C. TSIAPALIS	B.A., M.Sc., Ph.D. (Western Ont.)	Postdoctorate Fellow
L. P. VISENTIN	B.Sc. (St. Francis Xavier), M.S. (Detroit), Ph.D. (Michigan)	Postdoctorate Fellow
I. WIBERGER	Dr. agric. (Uppsala)	Postdoctorate Fellow

DIVISION OF BUILDING RESEARCH

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A. BLAGA	Dipl. Ing. Chim. (Caen), Ph.D. (McGill)	Associate Research Officer
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G. G. LITVAN	Dipl. Chem. Eotvos), Ph.D. (Toronto)	Associate Research Officer
V. S. RAMACHANDRAN	B.Sc. (Mysore), M.Sc. (Banaras), D.Phil. (Calcutta)	Associate Research Officer
T. RITCHIE	B.A.Sc. (Toronto)	Associate Research Officer
R. S. YAMASAKI	B.Sc., M.Sc. (Manitoba), Ph.D. (Wisconsin)	Associate Research Officer
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H. M. WHITEHEAD	B.Sc., Ph.D. (Dalhousie)	Assistant Research Officer
T. CIACH (Mrs.)	M.Sc., D.Sc. (Warsaw)	Postdoctorate Fellow
Building Physics Section		
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R. J. DONATO	B.Sc., M.Sc., Ph.D. (London)	Associate Research Officer
H. S. WARD	B.Sc., Ph.D. (Birmingham)	Associate Research Officer
D. M. CLARK	A.R.C.S.T. (Strathclyde), M.Sc. (Southhampton)	Assistant Research Officer
A. DEBRUIJN	B.Sc., M.Sc., Ph.D. (Delft)	Assistant Research Officer
R. H. FERAHIAN	B.Sc., M.Sc. (Imperial), D.I.C.	Assistant Research Officer
J. H. RAINER	B.A.Sc. (Brit. Col.), M.Sc. (Stanford), Ph.D. (Illinois)	Assistant Research Officer

DIVISION OF BUILDING RESEARCH—Continued

Name	*Degrees*	*Class Title*
Building Services Section		
D. G. STEPHENSON	B.A.Sc. (Toronto), D.I.C. Ph.D. (London)	Senior Research Officer
K. R. SOLVASON	B.E., M.E. (Sask.)	Senior Research Officer
W. G. BROWN	B.Sc., M.Sc. (Queen's), D.Sc. (E.T.H. Zurich)	Senior Research Officer
G. P. MITALAS	B.A.Sc., M.A.Sc. (Toronto)	Associate Research Officer
C. J. SHIRTLIFFE	B.Sc. (Manitoba), M.Sc. (Minnesota)	Associate Research Officer
G. T. TAMURA	B.Sc. (Manitoba)	Associate Research Officer
J. O. EDLER	B.E.Sc. (Sask.), M.E.Sc. (Sydney), Ph.D. (Sask.)	Assistant Research Officer
R. SAKAGUCHI	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Assistant Research Officer
J. R. SASAKI	B.A.Sc. (Toronto), M.Sc. (Calif.)	Assistant Research Officer
Building Structures Section		
W. R. SCHRIEVER	Dipl.C.E. (E.T.H. Zurich), M.Sc. (Harvard)	Senior Research Officer
W. G. PLEWES	B.Sc. (Manitoba), M.Sc. (Queen's)	Senior Research Officer
D. E. ALLEN	B.Sc. (Queen's), M.A.Sc. (Brit. Col.), Ph.D. (Illinois)	Associate Research Officer
W. A. DALGLIESH	B.Sc. (Alta.), M.Eng. (Carleton)	Associate Research Officer
D. A. LUTES	B.Sc. (New Bruns.), M.A.Sc. (Waterloo)	Assistant Research Officer
Fire Research Section		
G. W. SHORTER	B.A.Sc. (Toronto)	Senior Research Officer
M. GALBREATH	B.Sc. (Glasgow)	Senior Research Officer
T. Z. HARMATHY	Dipl. Ing. (Palatine Joseph), Dr. tech. (Die Technische Hochschule in Wien)	Senior Research Officer
T. T. LIE	Dipl. Ing. (Delft)	Associate Research Officer
J. H. MCGUIRE	B.Sc. (London)	Associate Research Officer
A. ROSE	B.Eng. (McGill)	Associate Research Officer
K. SUMI	B.A.Sc. (Toronto), Ph.D. (London)	Associate Research Officer
Y. TSUCHIYA	B.Sc., D.Eng. (Tokyo)	Associate Research Officer
G. J. WILLIAMS-LEIR	B.Sc. (Bristol)	Associate Research Officer
L. W. ALLEN	B.A.Sc., M.A.Sc. (Windsor)	Concrete Industry Fellow
W. W. T. STANZAK	B.A.Sc. (Toronto)	Steel Industry Fellow
Geotechnical Section		
L. W. GOLD	B.Sc. (Sask.), M.Sc., Ph.D. (McGill)	Senior Research Officer
E. PENNER	B.S.A., M.Sc. (Sask.)	Senior Research Officer
M. BOZOZUK	B.Sc., M.Sc. (Manitoba)	Associate Research Officer
R. J. E. BROWN	B.A., M.A. (Toronto), Ph.D. (Clark)	Associate Research Officer
K. N. BURN	B.E. (N. S. Tech.), M.Sc. (Illinois)	Associate Research Officer
W. J. EDEN	B.A.Sc. (Toronto)	Associate Research Officer
G. H. JOHNSTON	B.Sc. (Manitoba)	Associate Research Officer
P. SCHAERER	Dipl. C.E. (E.T.H. Zurich)	Associate Research Officer
G. P. WILLIAMS	B.A.Sc. (Brit. Col.), M.Sc. (Utah St. Agr. Coll.)	Associate Research Officer
R. FREDERKING	B.Sc. (Alta.), M.Sc. (London) Ph.D. (Illinois)	Assistant Research Officer
L. E. GOODRICH	B.Sc., M.Sc. (Alta.)	Assistant Research Officer
*D. W. BOYD	B.Sc., M.Sc. (Toronto)	Climatologist
Building Practice Group		
G. O. HANDEGORD	B.E. (Sask.), M.Sc. (Illinois)	Principal Research Officer
Construction Section		
C. R. CROCKER	D.S.O., B.Sc. (New Bruns.)	Senior Research Officer
G. G. BOILEAU	B. Eng. (McGill)	Associate Research Officer
J. K. LATTA	B.Arch. (McGill)	Assistant Research Officer
J. L. HALL	B.Arch. (McGill)	Assistant Research Officer

* Seconded to the Division of Building Research by the Department of Transport, Meteorological Services.

DIVISION OF BUILDING RESEARCH—Concluded

Name	*Degrees*	*Class Title*
Design Section		
M. C. BAKER	B.Eng., B.Arch. (McGill)	Senior Research Officer
G. K. GARDEN	B.Arch. (Manitoba)	Senior Research Officer
G. H. KUESTER	Dipl.Arch. (H.B.K. Berlin)	Associate Research Officer
Building Use Section		
R. S. FERGUSON	B.Arch. (McGill)	Senior Research Officer
J. PAULS	B.Arch. (Brit. Col.)	Junior Research Officer
Library		
E. R. CARSON (Miss)	B.Sc. (Mt. Allison), B.L.S. (McGill)	Librarian
E. BRUCK (Mrs.)	Absolutorium (Prague), B.L.S. (Ottawa)	Librarian
B. L. WYMAN (Miss)	B.A. (Queen's), B.L.S. (Ottawa)	Librarian
Publications		
M. A. GERARD (Miss)	B.A. (Queen's)	Editor
M. E. WIMBERLEY (Miss)	B.A. (Carleton)	Editor
F. MACWHIRTER (Mrs.)	B.A. (Carleton)	Editor
Codes and Standards Group		
H. B. DICKENS	B.A.Sc. (Toronto)	Senior Research Officer
Codes Secretariat		
J. M. ROBERTSON		Administrative Officer
J. W. SAWERS		Administrative Officer
J. J. SHAVER		Administrative Officer
J. P. VEZINA	B.A. (Montreal)	Translator
Codes Technical Section		
A. T. HANSEN	B.Sc. (New Bruns.)	Associate Research Officer
A. D. KENT	B.Sc. (Queen's)	Associate Research Officer
G. M. PRICE	B.Sc. (New Bruns.), M.A.Sc. (Waterloo)	Assistant Research Officer
Atlantic Regional Station		
D. C. TIBBETTS	B.E. (N. S. Tech.)	Senior Research Officer
J. I. DAVISON	B.Sc., M.Sc. (Mt. Allison)	Associate Research Officer
D. R. ROBSON	B.E. (N. S. Tech.)	Assistant Research Officer
Prairie Regional Station		
J. J. HAMILTON	B.Sc., M.Sc. (Manitoba)	Associate Research Officer
C. P. HEDLIN	B.Sc. (Sask.), M.Sc. (Minnesota), Ph.D. (Toronto)	Associate Research Officer
H. W. ORR	B.E., M.Sc. (Sask.)	Assistant Research Officer
British Columbia Regional Station		
W. H. BALL	B.E. (Sask.)	Senior Research Officer
Toronto Information Office		
E. V. GIBBONS	B.Sc. (Queen's)	Senior Research Officer

DIVISION OF CHEMISTRY

I. E. PUDDINGTON	B.Sc., (Mt. Allison), M.Sc., Ph.D. (McGill), F.R.S.C.	Director
F. P. LOSSING	B.A., M.A. (Western Ont.), Ph.D. (McGill), F.R.S.C.	Assistant Director
K. DENSMORE (Miss)	B.A. (Dalhousie)	Administrative Officer
G. A. YOUNG		Administrative Officer

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DIVISION OF CHEMISTRY—Continued

Name	*Degrees*	*Class Title*
Analytical Chemistry		
D. S. RUSSELL	B.A., M.A., (Toronto)	Senior Research Officer
S. S. BERMAN	B.A., M.A., Ph.D. (Toronto)	Senior Research Officer
R. IRONSIDE	B.Sc. (Manitoba)	Associate Research Officer
E. C. GOODHUE	B.Sc. (Bishop's)	Associate Research Officer
M. E. BEDNAS	B.Sc. (Manitoba)	Associate Research Officer
C. K. LAIRD	B.Sc., Ph.D. (Queen's)	Postdoctorate Fellow
Chemical Engineering		
W. S. PETERSON	B.Sc., M.Sc. (Alta.)	Senior Research Officer
W. GRAHAM	B.E., M.Sc. (Sask.), Ph.D. (McGill)	Associate Research Officer
S. SOURIRAJAN	B.Sc. (Annamalai), D.I.I.Sc. (Ch.E.), A.I.I.Sc., Ph.D. (Bombay), D.Eng. (Yale), Cert. Jet Propulsion (UCLA)	Senior Research Officer
C. E. CAPES	B.A.Sc. (Toronto), Ph.D. (Cantab.)	Associate Research Officer
B. KUNST	Dipl. Ing. Chem., Ph.D. (Zagreb)	Postdoctorate Fellow
G. R. RIGBY	B.E., Ph.D. (New South Wales)	Postdoctorate Fellow
T. MATSUURA	B.Sc., M.S., (Tokyo), D. Ing. (Berlin)	Postdoctorate Fellow
A. R. HAUCK	B.A.Sc. (Ottawa)	Guest Worker
Chemical Spectroscopy		
H. J. BERNSTEIN	B.A., M.A., Ph.D. (Toronto) F.R.S.C.	Principal Research Officer
W. F. MURPHY	B.Sc. (Case Inst. Tech.), Ph.D. (Wisconsin)	Assistant Research Officer
P. R. CAREY	B.Sc., Ph.D. (Sussex)	Postdoctorate Fellow
S. S. MOHANTY	B.Sc., M.Sc. (Utkal), Ph.D. (Kanpur)	Postdoctorate Fellow
Colloids		
I. E. PUDDINGTON	B.Sc. (Mt. Allison), M.Sc., Ph.D. (McGill), F.R.S.C.	Director
A. F. SIRIANNI	B.Sc. (Mt. Allison), Ph.D. (McGill)	Principal Research Officer
D. W. DAVIDSON	B.Sc., M.Sc. (New Bruns.), Ph.D. (Brown)	Senior Research Officer
S. K. GARG	B.Sc., M.Sc., Ph.D. (Allahabad)	Associate Research Officer
S. R. GOUGH	B.Sc., Ph.D. (Wales)	Assistant Research Officer
B. D. SPARKS	B.Sc., Ph.D. (London)	Assistant Research Officer
B. MORRIS	B.Sc., Ph.D. (Wales)	Postdoctorate Fellow
High Polymer		
S. BYWATER	B.Sc., Ph.D. (Leeds)	Principal Research Officer
A. M. EASTHAM	B.A., M.A. (Brit. Col.), Ph.D. (McGill)	Principal Research Officer
D. J. WORSFOLD	B.Sc., Ph.D. (London)	Senior Research Officer
S. K. BROWNSTEIN	B.A. (Sask.), Ph.D. (Chicago)	Senior Research Officer
J. E. L. ROOVERS	Lic. Sc., Dr.Sc. (Louvain)	Associate Research Officer
P. LACHANCE	B.A., B.Sc., D.Sc. (Laval)	Assistant Research Officer
V. C. ARMSTRONG	B.Sc., Ph.D. (Exeter)	Postdoctorate Fellow
P. G. HOOPER	B.Sc., Ph.D. (Birmingham)	Postdoctorate Fellow
B. S. JAMIESON	B.Sc. (Glasgow), Ph.D. (Strathclyde)	Postdoctorate Fellow
J. M. SANGSTER	B.Sc., M.Sc. (McGill), Ph.D. (Edinburgh)	Postdoctorate Fellow
High Pressure		
E. WHALLEY	B.Sc., Ph.D. (London), D.Sc. (London), F.R.S.C.	Principal Research Officer
G. S. KELL	M.A., Ph.D. (Toronto)	Associate Research Officer
P. T. T. WONG	B.Sc., M.Sc., (Full Tank), Ph.D. (New Bruns.)	Assistant Research Officer
D. D. KLUG	B.Sc., Ph.D. (Wisconsin)	Postdoctorate Fellow
S. A. K. HSIEH	B.Sc. (Shantung), Ph.D. (Southampton)	Postdoctorate Fellow
E. ENGELHARDT	Diplom., Ph.D. (Technische Hochschule, Munich)	Visiting Scientist
Hydrocarbon Chemistry		
K. U. INGOLD	B.Sc. (London), D. Phil. (Oxon.)	Principal Research Officer
E. C. HORSWILL	B.A., Ph.D., (Toronto)	Associate Research Officer

DIVISION OF CHEMISTRY—Continued

Name	*Degrees*	*Class Title*
Hydrocarbon Chemistry—Concluded		
J. A. HOWARD	B.Sc., Ph.D. (Birmingham)	Associate Research Officer
J. L. BROKENSHIRE	B.Sc., Ph.D. (Exeter)	Postdoctorate Fellow
T. P. FRANGOPOL	Ingenieur (Iassy), Specialist, (Bucarest), Docteur Ingenieur, (Timisoara)	Postdoctorate Fellow
T. GILLAN	B.Sc., (Belfast), Ph.D. (Alta.)	Postdoctorate Fellow
S. KORCEK	M.Sc., Ph.D. (Bratislava)	Postdoctorate Fellow
Kinetics, Protochemistry and Catalysis		
R. J. CVETANOVIC	B.Sc., (Edinburgh), B.A.Sc., (Belgrade), M.A., Ph.D. (Toronto), F.R.S.C.	Principal Research Officer
Y. AMENOMIYA	B.Eng. (Tokyo Inst.), D.Sc., (Hokkaido)	Senior Research Officer
R. A. BACK	B.Sc., M.Sc. (Western Ont.), Ph.D. (McGill)	Senior Research Officer
K. O. KUTSCHKE	B.Sc. (Western Ont.), Ph.D. (Rochester), F.R.S.C.	Principal Research Officer
F. P. LOSSING	B.A., M.A. (Western Ont.), Ph.D. (McGill), F.R.S.C.	Assistant Director
G. PARASKEVOPOULOS	B.Eng. (Tech. Univ., Athens), M.A.Sc. (Toronto), Ph.D. (McGill)	Assistant Research Officer
R. F. POTTIE	B.Sc. (St. Francis Xavier), Ph.D. (Notre Dame)	Senior Research Officer
K. F. PRESTON	M.A., Ph.D. (Cantab.)	Associate Research Officer
R. W. J. YIP	B.Sc. (Brit. Col.), B.Sc., Ph.D. (Western Ont.)	Assistant Research Officer
R. ATKINSON	B.A., Ph.D. (Cambridge)	Postdoctorate Fellow
J. P. BRIGGS	B.Sc. (Leeds), M.Sc., Ph.D. (Nuclear Tech. Imperial College)	Postdoctorate Fellow
J. DUNSTON (Miss)	B.Sc., M.A., Ph.D. (Toronto)	Postdoctorate Fellow
D. E. HOPKINS	B.Sc., Ph.D. (Hull)	Postdoctorate Fellow
D. H. LISTER	B.Sc., Ph.D. (Southampton)	Postdoctorate Fellow
P. H. MICHAUD	Diplom. Ingenieur, Lic.-es Sci. (Nancy), Docteur-es-Sci. (Laval)	Postdoctorate Fellow
L. M. QUICK	B.Sc., Ph.D. (Cardiff)	Postdoctorate Fellow
P. M. SCOTT	B.Sc., Ph.D. (Sheffield)	Postdoctorate Fellow
T. YOKOTA	B.Sc. (Tokyo), Ph.D. (The Catholic U. of America)	Postdoctorate Fellow
K. HUKUDA	Doctor of Science, (Kyushu)	Visiting Scientist
KONASEWICH, D.	B.Sc. (Calgary), Ph.D. (Minnesota)	Guest Worker
Metallic Corrosion and Oxidation		
M. COHEN	B.A. (Brandon Coll.), M.A., Ph.D. (Toronto)	Principal Research Officer
D. CAPLAN	B.Sc., M.Sc. (Queen's), Ph.D. (Rensselaer Polytech. Inst.)	Senior Research Officer
M. J. GRAHAM	B.Sc., Ph.D. (Liverpool)	Assistant Research Officer
R. J. HUSSEY	B.Sc., Ph.D. (Exeter)	Associate Research Officer
D. F. MITCHELL	B.Sc. (Indiana), Ph.D. (Virginia)	Assistant Research Officer
P. B. SEWELL	M.Sc., Ph.D. (West Australia)	Senior Research Officer
D. B. GIBBS	B.Sc. (Brit. Col.), M.A., Ph.D. (Toronto)	Postdoctorate Fellow
Metallurgic Chemistry		
W. A. ALEXANDER	B.A., M.A. (Queen's), Ph.D. (McGill)	Principal Research Officer
L. D. CALVERT	B.Sc., B.A., M.Sc., Ph.D. (New Zealand)	Senior Research Officer
J. B. TAYLOR	B.Sc., M.Sc., Ph.D. (Manchester)	Senior Research Officer
A. A. ANTONIOU	B.Sc. (Thessaloniki), Ph.D. (Toronto)	Associate Research Officer
C. M. HURD	B.Sc., Ph.D. (Hull)	Associate Research Officer
J. E. A. ALDERSON	B.Sc., M.Sc., Ph.D. (West Australia)	Associate Research Officer
J. J. MURRAY	B.Sc., Ph.D. (Queen's)	Assistant Research Officer
S. ONO	B.Eng., M.Eng., D.Eng. (Tokyo)	Postdoctorate Fellow
L. USNER	Dipl. Eng., Dr. Techn. (Vienna)	Postdoctorate Fellow
L. KERTESZ	Diplom., Ph.D. (Kiev)	Visiting Scientist

DIVISION OF CHEMISTRY—Concluded

Name	*Degrees*	*Class Title*
Molecular Structures		
A. H. REDDOCH	B.Sc., M.Sc. (Queen's), Ph.D. (Calif.)	Associate Research Officer
D. F. WILLIAMS	B.Sc. (Nottingham), M.Sc., Ph.D. (Manitoba)	Associate Research Officer
J. D. HALLIDAY	B.Sc., M.Sc. (Memorial U. of Nfld.), D.Phil. (Oxon.)	Postdoctorate Fellow
M. KAPLANSKY	B.Sc., Ph.D. (McGill)	Postdoctorate Fellow
S. V. KULKARNI	B.Sc., M.Sc. (Nagpur), Ph.D. (Chicago)	Postdoctorate Fellow
N. WAKAYAMA	B.Sc., M.Sc., D.Sc. (Tokyo)	Postdoctorate Fellow
Organic Spectrochemistry		
R. N. JONES	B.Sc., M.Sc., Ph.D., D.Sc., (Manchester), F.R.S.C.	Principal Research Officer
D. ESCOLAR	Ph.D. (Madrid)	Postdoctorate Fellow
H. H. MANTSCH	Dipl. Chimie, D.Sc. (Cluj)	Postdoctorate Fellow
P. NEELAKANTAN	B.Sc., M.Sc. (Kerala), Ph.D. (Indian Inst. of Science, Bangalore)	Postdoctorate Fellow
S. CATALIOTTI	Dr. in chimica (Perugia)	Canada Council Fellow
E. SPINNER	B.Sc., M.Sc., Ph.D. (Manchester)	Visiting Scientist
Organic Synthesis		
L. C. LEITCH	B.Sc. (Ottawa), D.Sc. (Laval)	Senior Research Officer
R. RENAUD	B.Sc., M.Sc., Ph.D. (Ottawa)	Assistant Research Officer
W. WYSOCKA (Mrs.)	B.Sc., Ph.D. (Poznan)	Postdoctorate Fellow
MYINT MYINT THAN (Miss)	B.Sc., (Arts & Science Univ. Mandalay)	IAEA Fellow
Textile Chemistry		
D. M. WILES	B.Sc., M.Sc. (McMaster), Ph.D. (McGill)	Senior Research Officer
D. J. CARLSSON	B.Sc., Ph.D. (Birmingham)	Associate Research Officer
A. S. TWEEDIE (Miss)	B.Sc., M.Sc. (Manitoba)	Associate Research Officer
P. J. J. B. BLAIS	B.Sc., Ph.D. (McGill)	Assistant Research Officer
M. T. MITTON (Miss)	B.Sc. (Mt. Allison)	Assistant Research Officer
J. D. COONEY	B.Sc., M.Sc. (Carleton)	Assistant Research Officer
M. DAY	B. Technol. (Bradford), Ph.D. (Aberystwyth)	Postdoctorate Fellow
Theoretical Studies		
M. L. KLEIN	B.Sc., Ph.D. (Bristol)	Associate Research Officer
C. MAVROYANNIS	B.Eng. (Tech. Univ. Athens), Ph.D. (McGill), D. Phil. (Oxon.)	Associate Research Officer
F. D. PEAT	B.Sc., M.Sc., Ph.D. (Liverpool)	Assistant Research Officer
W. SIEBRAND	Cand. Drs., Dr. (Amsterdam)	Associate Research Officer
R. L. SOMORJAI	B.Sc. (McGill,), Ph.D. (Princeton)	Assistant Research Officer
S. C. BARANOVSKY	Dipl. Eng. Mining & Metall. (Chille), Ph.D. (Sheffield)	Postdoctorate Fellow
J. A. DEVERIN	Ph.D. (Lausanne)	Postdoctorate Fellow
J. LAM	B.A. (Rice), Ph.D. (Cal. Inst. Tech.)	Postdoctorate Fellow
S. MALM (Miss)	B.Sc. (Edmonton), Ph.D. (Bristol)	Postdoctorate Fellow
O. S. MORTENSEN	Ph.D. (Copenhagen)	Postdoctorate Fellow
R. W. MUNN	B.Sc., Ph.D. (Bristol)	Postdoctorate Fellow
T. C. P. YUE	B.Sc. (Hong Kong), Ph.D. (Brit. Col.)	Postdoctorate Fellow
Thermochemistry		
G. C. BENSON	B.A., M.A., Ph.D. (Toronto) F.R.S.C.	Principal Research Officer
D. E. G. JONES	B.Sc., Ph.D. (Western Ont.)	Postdoctorate Fellow
J. POLAK	M.Sc., Ph.D. (Prague)	Postdoctorate Fellow
I. A. WEEKS	B.Sc., M.Sc. (New England), Ph.D. (Tasmania)	Postdoctorate Fellow

DIVISION OF MECHANICAL ENGINEERING

Name	*Degrees*	*Class Title*
Director's Office		
D. C. MACPHAIL	B.A.Sc. (Brit. Col.), M.S. (Cal. Inst. Tech.), Ph.D. (Cantab.)	Director
A. S. JACKSON	D.F.C., Bach. Air Trans. (Purdue)	Projects Officer
M. O'NEILL		Administrative Officer
Mechanics		
Analysis Laboratory		
R. E. GAGNÉ	B.Sc., M.Sc. (Manitoba), Ph.D. (London)	Senior Research Officer
I. H. MUFTI	B.Sc. (Sind), M.Sc. (Karachi), Ph.D. (Brit. Col.)	Associate Research Officer
L. BIRTA	B.A.Sc. (Toronto), M.S., Ph.D. (Case Inst. Tech.)	Assistant Research Officer
P. W. U. GRAEFE	B.A.Sc. (Toronto), M.A.Sc., Ph.D. (Waterloo)	Assistant Research Officer
Instrument Laboratory		
S. H. G. CONNOCK	B.Sc., D.I.C. (London)	Senior Research Officer
C. A. M. SMITH	B.A.Sc., M.A. (Toronto)	Senior Research Officer
E. H. BOWLER	B.E. (Sask.)	Associate Research Officer
T. WEIBUST	B.A.Sc. (Toronto)	Associate Research Officer
R. C. ROGGEVEEN	B.A.Sc. (Brit. Col.). M.Eng. (McGill)	Assistant Research Officer
C. M. G. ZWARTS	M.Sc. (Delft)	Assistant Research Officer
K. G. WHALE	B.A.Sc., M.A.Sc. (Brit. Col.)	Junior Research Officer
Control Systems Laboratory		
J. A. TANNER	B.Sc. (London), M.E. (Yale), Ph.D. (Wales)	Principal Research Officer
L. J. BUCK	B.Sc. (London), Ph.D. (London)	Associate Research Officer
P. A. HAMILL	MSc. (Nat'l. Univ. Ireland)	Associate Research Officer
W. F. HAYES	B.E. (McGill), D.C.Ae. (Coll. Aeronautics)	Associate Research Officer
T. KASVAND	B.A.Sc., M.A.Sc. (Toronto), Ph.D. (Brit. Col.)	Associate Research Officer
M. MILNER	B.Sc., Ph.D. (Witwatersrand)	Associate Research Officer
L. K. NENONEN	B.A.Sc. (Toronto), M.Eng. (Carleton)	Associate Research Officer
C. M. WOODSIDE	B.A.Sc. (Toronto), Ph.D. (Cantab.)	Associate Research Officer
A. O. QUANBURY	B.Sc. (Queen's), M.A.Sc. (Toronto)	Assistant Research Officer
H. G. TUCKER	B.S.A., (Guelph), B.A.Sc. (Toronto)	Junior Research Officer
Hydrodynamics		
Hydraulics Laboratory		
S. INCE	B.Sc. (Robert Coll.), M.Sc., Ph.D. (Iowa)	Senior Research Officer
J. E. FEIR	B.Sc. (Alberta), M.Sc. (London) Ph.D. (Cantab.)	Senior Research Officer
E. R. R. FUNKE	B.Sc. (Queen's), M.Sc. (London)	Associate Research Officer
J. PLOEG	Civil Engineer (Delft)	Associate Research Officer
Y. L. LAU	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Assistant Research Officer
B. D. PRATTE	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Assistant Research Officer
N. L. CROOKSHANK	B.Sc., (Ottawa)	Junior Research Officer
W. W. JAMIESON	B.A.Sc. (Ottawa)	Junior Research Officer
Ship Laboratory		
S. T. MATHEWS	Naval Architecture (Royal Naval Coll.), M.Sc. (Durham)	Senior Research Officer
D. GOSPODNETIC	B.Sc., Ph.D. (Zagreb)	Senior Research Officer
J. T. TOTHILL	B.Sc. (Glasgow)	Senior Research Officer
M. MICHAILIDIS	Dipl. Ing., (Tech. Univ., Berlin)	Junior Research Officer
M. D. MILES	B.Sc. (Dalhousie), S.M. (Mass. Inst. Tech.)	Junior Research Officer
Thermodynamics		
Gas Dynamics Laboratory		
A. J. BACHMEIER	B.E. (Sask.)	Principal Research Officer
P. SAVIC	Can. Phil. (Basel), Ph.D. (London)	Principal Research Officer

DIVISION OF MECHANICAL ENGINEERING—Concluded

Name	*Degrees*	*Class Title*
Thermodynamics—Concluded		
Gas Dynamics Laboratory—Concluded		
R. A. TYLER	B.Sc. (London)	Principal Research Officer
E. H. DUDGEON	B.A.Sc., M.A.Sc. (Toronto)	Senior Research Officer
E. S. TURNER	B.A.Sc. (Toronto)	Senior Research Officer
B. S. LARKIN	B.Sc., Ph.D. (London)	Associate Research Officer
A. H. MAKOMASKI	B.Sc., Ph.D. (London)	Associate Research Officer
E. PANARELLA	Ph.D. (Univ. Naval Inst., Naples)	Associate Research Officer
H. D. HARRIS	B.E., M.Eng.Sc. (Sydney)	Assistant Research Officer
J. H. W. LAU	B.A.Sc., M.A.Sc. (Toronto), Ph.D. (Ottawa)	Assistant Research Officer
I. R. G. LOWE	B.Sc. (New Brunswick), M.Sc., Ph.D. (Birmingham)	Assistant Research Officer
E. J. STUBBE	Eng. (Catholic Univ. of Louvain, Belgium), M.A.Sc. (Toronto)	Assistant Research Officer
R. G. WILLIAMSON	B.Sc., M.Sc., (Bristol)	Assistant Research Officer
Engine Laboratory		
E. P. COCKSHUTT	B.A.Sc. (Toronto), S.M., Sc.D. (Mass. Inst. Tech.) F.C.A.S.I.	Principal Research Officer
H. S. FOWLER	B.Sc. (London)	Senior Research Officer
J. J. SAMOLEWICZ	M.E. (Lwow)	Senior Research Officer
M. S. CHAPPELL	B.A.Sc. (Brit. Col.), M.Eng. (Carleton)	Associate Research Officer
G. A. MACAULAY	B.Eng. (McGill)	Associate Research Officer
F. RUETER	B.A.Sc. (Toronto)	Associate Research Officer
U. W. SCHAUB	B.Sc. (Queen's), S.M. (Mass. Inst. Tech.)	Associate Research Officer
A. A. SWIDERSKI	Dipl. M.E., (Inst. Tech., Danzig)	Associate Research Officer
[1]G. KRISHNAPPA	B.E., (Mysore), M.Sc., (Indian Inst. of Sci.), Ph.D., (Waterloo)	Assistant Research Officer
Low Temperature Laboratory		
T. R. RINGER	B.A.Sc. (Toronto)	Senior Research Officer
N. D. DURIE	B.A.Sc. (Toronto), M.E.Sc., (Western Ont.)	Associate Research Officer
J. F. LANE	B.Sc. (Queen's)	Associate Research Officer
J. R. STALLABRASS	B.Sc. (London)	Associate Research Officer
T. M. MAZUR	M.A. (Acad. of Mining & Metalurgy, Cracow)	Junior Research Officer
Fuels and Lubricants Laboratory		
R. B. WHYTE	B.Sc., Ph.D. (Aberdeen)	Senior Research Officer
R. J. P. SANDRI	Dr. Tech. Sc., Dipl. Ing. (Vienna)	Senior Research Officer
L. GARDNER	B.Sc. (London)	Associate Research Officer
L. D. NEW	B.Sc. (Alberta)	Associate Research Officer
P. L. STRIGNER	B.Sc. (Queen's)	Associate Research Officer
C. DAYSON	B.Sc., Ph.D. (Wales)	Assistant Research Officer
J. K. S. WONG	B.E. (Nova Scotia Tech.), M. Eng. (Carleton)	Assistant Research Officer

NATIONAL AERONAUTICAL ESTABLISHMENT

Director's Office		
F. R. THURSTON	B.Sc. (London)	Director
W. F. CAMPBELL	B.A. (McMaster), M.A. (Cantab.)	Senior Research Officer
G. F. W. MCCAFFREY	B.Sc. (Queen's)	Associate Research Officer
D. A. HEWITT		Administrative Officer

[1] Leave of Absence

NATIONAL AERONAUTICAL ESTABLISHMENT—Continued

Name	*Degrees*	*Class Title*
Aerodynamics		
Low Speed Aerodynamics		
R. J. TEMPLIN	B.A.Sc. (Toronto)	Senior Research Officer
H. H. KELLAND	B.A.Sc. (Brit. Col.)	Senior Research Officer
R. L. WARDLAW	B.A.Sc. (Toronto), Dipl. (McGill) M.Eng. (Carleton)	Senior Research Officer
D. H. HENSHAW	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Associate Research Officer
W. E. LAUNDRY	B.A.Sc., M.A.Sc. (Toronto)	Associate Research Officer
R. S. RANGI	B.A. (Sikh Nat'l. Coll.), M.A.Sc. (Toronto)	Associate Research Officer
R. H. WICKENS	B.Eng. (McGill)	Associate Research Officer
Y. NISHIMURA	B.A.Sc. (Brit. Col.), M.A.Sc. (Toronto)	Assistant Research Officer
P. SOUTH	B.A.Sc. (Brit. Col.)	Assistant Research Officer
N. M. STANDEN	B.A.Sc. (Brit. Col.), M.Eng. (McGill)	Assistant Research Officer
K. R. COOPER	B.A. (Western Ont.), M.A.Sc. (Toronto)	Junior Research Officer
High Speed Aerodynamics		
W. J. RAINBIRD	B.E. (New Zealand), D.C.Ae. (Coll. Aeronautics)	Senior Research Officer
L. H. OHMAN	Civil Eng. (Royal Inst. Tech., Sweden)	Senior Research Officer
D. BROWN	B.Sc. (Bristol), M.A.Sc. (Toronto) Ph.D. (Bristol)	Associate Research Officer
Y. Y. CHAN	B.Sc. (Nat'l. University, Taiwan), M.E.Sc. (Sydney), Ph.D. (Toronto)	Associate Research Officer
J. J. KACPRZYNSKI	M.Sc. (Warsaw Tech.), Ph.D. (Polish Acad. Sci.)	Associate Research Officer
E. G. ATRAGHJI	B.Sc. (London)	Assistant Research Officer
A. J. BOWKER	B.A.Sc. (Brit. Col.)	Assistant Research Officer
[1]R. S. CRABBE	B.Sc. (Queen's), M.A.Sc. (Toronto)	Assistant Research Officer
R. C. DIXON	B.Sc. (Southampton)	Assistant Research Officer
R. C. GALWAY	B.Sc., M.Sc. (Queen's University of Belfast)	Assistant Research Officer
B. H. K. LEE	B.E., M.E., Ph.D., (McGill)	Assistant Research Officer
M. MOKRY	Dipl. Ing. (Prague), P.G., C.Sc. (Czech. Acad. Sci.)	Assistant Research Officer
T. ONNO	B.Sc. (New Brunswick)	Assistant Research Officer
D. J. PEAKE	B.Sc., M.Sc. (Bristol)	Assistant Research Officer
D. J. JONES	B.Sc., M.Sc., (Manchester)	Computer Systems Officer
Unsteady Aerodynamics		
K. J. ORLIK-RUCKEMANN	M.Sc. (Royal Inst. Tech., Sweden)	Senior Research Officer
L. T. CONLIN	B.A. (Western Ont.)	Associate Research Officer
L. ELIAS	B.Sc. (Carleton), Ph.D. (McGill)	Associate Research Officer
J. G. LABERGE	B.Eng. (McGill), M.Sc. (Cal. Inst. Tech.)	Associate Research Officer
P. A. ADAMS	B.Sc. (Queen's)	Assistant Research Officer
A. T. FROEBEL	B.S.E., M.S.E. (Michigan)	Assistant Research Officer
Flight Research		
A. D. WOOD	B.Sc., D.I.C. (London)	Principal Research Officer
E. A. GODBY	B.Sc., M.Sc. (Alberta)	Senior Research Officer
D. G. GOULD	B.A.Sc., M.A.Sc., Ph.D. (Toronto)	Senior Research Officer
H. T. STEVINSON	B.Sc. (Alta.)	Senior Research Officer
R. C. BAKER	B.Eng. (McGill), M.Sc. (Stanford)	Associate Research Officer
D. F. DAW	B.Sc. (Alta.)	Associate Research Officer
H. N. C. LYSTER	B.A.Sc. (Toronto), M.Eng. (Carleton)	Associate Research Officer
G. K. MATHER	B.Sc., M.Sc. (McGill)	Associate Research Officer

[1] Educational Leave

NATIONAL AERONAUTICAL ESTABLISHMENT—Concluded

Name	*Degrees*	*Class Title*
Flight Research—Concluded		
D. M. McGregor	B.A.Sc., M.A.Sc. (Toronto)	Associate Research Officer
W. E. B. Roderick	B.A.Sc., M.A.Sc., (Toronto)	Associate Research Officer
M. W. Strome	B.Sc. (Alta.), M.A.Sc. (Brit. Col.) Ph.D. (Carnegie)	Associate Research Officer
D. N. Davis	B.Sc. (Alta.), M.Sc., (London)	Assistant Research Officer
J. N. Devilliers	B.Sc. (Edinburgh), Ph.D. (Cantab.)	Assistant Research Officer
K. H. Doetsch	B.Sc., D.I.C., Ph.D. (London)	Assistant Research Officer
W. S. Hindson	B.A.Sc., M.A.Sc. (Toronto)	Assistant Research Officer
K. Lum	B.A.Sc. (Toronto)	Assistant Research Officer
J. I. MacPherson	B.A.Sc., M.A.Sc. (Toronto)	Assistant Research Officer
D. S. Treddenick	B.Sc., (Manitoba). D.C.Ae. (Coll. Aeronautics)	Assistant Research Officer
B. Caiger	D.C.Ae. (Coll. of Aeronautics, Cranfield)	Research Council Officer
Structures and Materials		
A. H. Hall	B.Sc. (Alta.), M.Sc. (Cal. Inst. Tech.)	Principal Research Officer
J. A. Dunsby	B.Sc., M.Sc. (London) (F.R.Ae.S.)	Senior Research Officer
G. R. Cowper	B.Sc., M.Sc. (Queen's), Ph.D. (Brown)	Associate Research Officer
G. M. Lindberg	B.Sc. (Alta.), Ph.D. (Cantab.)	Associate Research Officer
H. F. L. Pinkney	B.Sc. (Alta.), M.Sc., Ph.D. (Stanford)	Associate Research Officer
R. Westley	B.Sc. (London), D.C.Ae. (Coll. Aeronautics, Cranfield)	Associate Research Officer
W. Wiebe	B.Sc. (Carleton)	Associate Research Officer
G. L. Basso	B.Sc. (St. Francis Xavier), B.E. (N.S. Tech.), M.Sc. (London)	Assistant Research Officer
P. M. Huculak	B.Sc. (Alta.), M.A.Sc. (Waterloo)	Assistant Research Officer
M. D. Olson	B.A.Sc. (Brit. Col.), M.S., Ph.D. (Cal. Inst. Tech.)	Assistant Research Officer
R. F. Scott	B.E. (N.S. Tech.)	Assistant Research Officer
J. M. Trenouth	B.Sc., M.Sc. (Western Ont.)	Assistant Research Officer
W. Wallace	B.Sc., Ph.D. (Manchester)	Assistant Research Officer
E. P. Whelan	B.Sc., M.Met., Ph.D. (Sheffield)	Assistant Research Officer
A. Barszczewski	B.Sc. (Carleton)	Research Council Officer
P. D. McLean	B.Sc., M.Sc. (Acadia)	Research Council Officer
E. R. Welbourne	D.C.Ae. (Coll. of Aeronautics, Cranfield)	Research Council Officer
H. Tulloch	B.A. (Sask.)	Computer Systems Officer
Reports		
E. Adair		Editor

PRAIRIE REGIONAL LABORATORY

Director's Office		
H. R. Sallans	B.Sc., M.Sc., (Sask.), Ph.D. (McGill)	Director
B. M. Craig	B.S.A., M.Sc. (Sask.), Ph.D. (Minnesota)	Associate Director
A. B. Flavell (Miss)	B.A. (Sask.)	Administrative Assistant
Physiology and Biochemistry of Fungi		
R. H. Haskins	B.A., M.A. (Western Ont.), Ph.D. (Harvard)	Principal Research Officer
J. C. MacDonald	B.Sc. (Alta.), M.Sc., Ph.D. (Wisconsin)	Senior Research Officer
J. J. Child	B.Sc., Ph.D. (Durham)	Associate Research Officer
G. P. Slater	B.Sc. (Aberdeen), M.Sc. (Sask.), Ph.D. (Queen's, Belfast)	Associate Research Officer
Physiology and Biochemistry of Bacteria		
F. J. Simpson*	B.Sc., M.Sc. (Alta.), Ph.D. (Wisconsin)	Senior Research Officer

* Transferred to Atlantic Regional Laboratory–1 April, 1970.

PRAIRIE REGIONAL LABORATORY—Concluded

Name	*Degrees*	*Class Title*
Physiology and Biochemistry of Bacteria—Concluded		
E. R. BLAKLEY	B.S.A., M.Sc. (Sask.), Ph.D. (Minnesota)	Senior Research Officer
D. E. EVELEIGH	B.Sc. (London), Ph.D. (Exeter)	Associate Research Officer
T. A. G. LARUE	B.S., M.Sc. (Manitoba), Ph.D. (Iowa)	Associate Research Officer
D. B. HARPER	B.S. (Bristol), Ph.D. (London)	Postdoctorate Fellow
T. OKA	B.Sc., M.Sc., Ph.D. (Tokyo)	Postdoctorate Fellow
Plant Biochemistry		
L. R. WETTER	B.S., M.Sc. (Alta.), Ph.D. (Wisconsin)	Senior Research Officer
O. L. GAMBORG	B.Sc., M.Sc. (Alta.), Ph.D. (Sask.)	Associate Research Officer
R. A. MILLER	B.Sc., B.Ed., Ph.D. (Alta.)	Associate Research Officer
W. F. STECK	B.Eng. (McGill), Ph.D. (Sask.)	Associate Research Officer
E. W. UNDERHILL	B.S.P., M.Sc. (Sask.), Ph.D. (Rhode Island)	Associate Research Officer
J. E. WATKIN	B.A. (Cantab.), Ph.D. (Wales)	Associate Research Officer
K.-N. KAO	B.S. (Chung-Hsing), M.S.A. (Guelph), Ph.D. (Sask.)	Postdoctorate Fellow
M. MATSUO	B.Sc., M.Sc., Ph.D. (Tokyo)	Postdoctorate Fellow
F. CONSTABEL	Dr. rer. nat. (Gottingen)	Visiting Scientist
J. BAYLEY (Miss)	B.Sc. (Bradford Univ. of Technol.)	Guest Research Worker
W. KELLER	B.Sc. Agr. (Sask.)	Guest Research Worker
Chemistry of Natural Products		
B. M. CRAIG	B.S.A., M.Sc. (Sask.), Ph.D. (Minnesota)	Principal Research Officer
P. A. J. GORIN	B.Sc., Ph.D. (Bristol)	Senior Research Officer
E. M. VON RUDLOFF	B.Sc., M.Sc., D.Sc. (Pretoria)	Senior Research Officer
A. P. TULLOCH	B.Sc., Ph.D. (Glasgow)	Senior Research Officer
A. J. FINLAYSON	B.A., M.Sc. (Brit. Col.), Ph.D. (Sask.)	Associate Research Officer
S. L. MACKENZIE	B.Sc., Ph.D. (Edinburgh)	Assistant Research Officer
M. MAZUREK	B.S.A. (Sask.)	Assistant Research Officer
L. A. GODING	B.S., M.S., Ph.D. (New Mexico)	Postdoctorate Fellow
Engineering and Process Development		
H. R. SALLANS	B.Sc., M.Sc. (Sask.), Ph.D. (McGill)	Director
K. L. PHILLIPS	B.E., M.Sc., Ph.D. (Sask.)	Research Council Officer
J. F. T. SPENCER	B.Sc., M.Sc. (Alta.), Ph.D. (Sask.)	Senior Research Officer
C. G. YOUNGS	B.Sc. (Alta.), M.Sc., Ph.D. (Sask.)	Senior Research Officer
P. S. S. DAWSON	B.Sc., M.Sc. (Birmingham), Ph.D. (Sask.)	Associate Research Officer
W. G. W. KURZ	Ph.D. (Vienna)	Associate Research Officer
H. GLÄTTLI	Diploma, Ing. Agron., Dr. Sc. Techn., (Swiss Fed. Inst. of Tech.)	Postdoctorate Fellow

DIVISION OF PHYSICS

Director's Office		
A. E. DOUGLAS	B.A., M.A. (Sask.), Ph.D. (Penn. State), F.R.S.C., F.R.S.	Director
I. B. MCDIARMID	B.A., M. A. (Queen's), Ph.D. (Manchester)	Assistant Director
H. PRESTON-THOMAS	B.Sc., Ph.D. (Bristol)	Assistant Director
R. C. BURSTOW		Administrative Officer
M. N. BEDARD (Miss)		Administrative Officer
Acoustics		
G. J. THIESSEN	M.Sc. (Sask.), Ph.D. (Columbia), F.R.S.C.	Principal Research Officer
T. F. W. EMBLETON	B.Sc., Ph.D., D.Sc. (London)	Senior Research Officer
E. A. G. SHAW	B.Sc., Ph.D. (London)	Senior Research Officer
J. E. PIERCY	B.A.Sc., M.A.Sc. (Brit. Col.), Ph.D. (London)	Senior Research Officer

DIVISION OF PHYSICS—Continued

Name	*Degrees*	*Class Title*
Acoustics—Concluded		
N. OLSON	B.A., M.A. (Sask.), Ph.D. (Toronto)	Associate Research Officer
F. E. TOOLE	B.Sc. (New Bruns.), Ph.D. (Imperial College)	Assistant Research Officer
A. J. BRAMMER	B.Sc., Ph.D. (Exeter)	Assistant Research Officer
Cosmic Rays and High Energy Particle Physics		
I. B. MCDIARMID	B.A., M.A. (Queen's), Ph.D. (Manchester)	Assistant Director
E. P. HINCKS	B.A., M.A. (Toronto)	Principal Research Officer
J. KATZMAN	B.Sc., M.Sc., Ph.D. (McGill)	Senior Research Officer
M. D. BELL (Mrs.)	B.Sc., Ph.D. (Edinburgh)	Associate Research Officer
M. BERCOVITCH	B.Sc., M.Sc. (McGill), Ph.D. (Yale)	Associate Research Officer
E. E. BUDZINSKI	B.Sc., M.Sc. (Alta.)	Associate Research Officer
J. R. BURROWS	B.A., M.A., Ph.D. (Toronto)	Associate Research Officer
C. K. HARGROVE	B.A. (New Bruns.), B.Sc., M.Sc., Ph.D. (McGill)	Associate Research Officer
B. JUDEK (Mrs.)	B.Sc., Ph.D. (Edinburgh)	Associate Research Officer
B. A. WHALEN	B.Sc. (Wash.), M.Sc., Ph.D. (Brit. Col.)	Associate Research Officer
J. M. FIRTH	B.A. (Cantab.)	Assistant Research Officer
R. J. MCKEE	B.Sc. (Case Inst.), M.Sc., Ph.D. (Chicago)	Assistant Research Officer
I. DUBAL	Dipl. Phys., D. ès Sci. (Geneva)	Postdoctorate Fellow
A. HASHIM	B.Sc., M.Sc. (Karachi), D.I.C., Ph.D. (Imperial)	Postdoctorate Fellow
J. R. MILLER	B.E., M.Sc., Ph.D. (Sask.)	Postdoctorate Fellow
W. H. WRIGHT	B.Sc., B.Sc. (Hon.), Ph.D. (Rhodes)	Postdoctorate Fellow
Diffraction Optics		
G. LANSRAUX	Bacc., License, Dil. Et. Sup., Doctorat d'Etat Sc. Phys. (Paris)	Senior Research Officer
B. G. WHITFORD	B.Sc., M.Sc., Ph.D. (McGill)	Associate Research Officer
L.-P. BOIVIN	B.Sc., Ph.D. (Ottawa)	Postdoctorate Fellow
Electricity		
J. T. HENDERSON	M.B.E., B.Sc., M.Sc. (McGill), Ph.D. (London), F.R.S.C., F.I.E.E.E.	Principal Research Officer
A. F. DUNN	B.Sc., M.Sc. (Dalhousie), Ph.D. (Toronto)	Senior Research Officer
A. G. MUNGALL	B.A.Sc., M.A.Sc. (Brit. Col.), Ph.D. (McGill)	Senior Research Officer
R. BAILEY	B.Sc. (Sask.)	Associate Research Officer
H. DAAMS	Dipl. Ing. (Delft)	Associate Research Officer
D. MORRIS	B.Sc., Ph.D. (London)	Associate Research Officer
L. G. TURNBULL	B.Sc. (Mt. Allison), M.A. (Dalhousie), Ph.D. (Toronto)	Associate Research Officer
S. H. TSAO	B.A.Sc., M.A.Sc. (Brit. Col.), Ph.D. (Birmingham)	Assistant Research Officer
G. H. WOOD	B.A.Sc., M.A.Sc., Ph.D. (Brit. Col.)	Assistant Research Officer
Heat and Solid State Physics		
H. PRESTON-THOMAS	B.Sc., Ph.D. (Bristol)	Assistant Director
R. J. BERRY	B.Sc., M.Sc. (Queen's)	Senior Research Officer
T. M. DAUPHINEE	B.A., M.A., Ph.D. (Brit. Col.)	Senior Research Officer
E. H. MCLAREN	B.Sc., M.Sc. (Manitoba)	Senior Research Officer
R. E. BEDFORD	B.Sc., (Manitoba), M.A., Ph.D., (Brit. Col.)	Associate Research Officer
J. ANCSIN	B.Sc., M.Sc., Ph.D. (Ottawa)	Assistant Research Officer
C. G. M. KIRBY	B.Sc. (Carleton)	Assistant Research Officer
J. D. SANKEY	B.Eng. (McGill), M.Sc. (Cantab.)	Assistant Research Officer
High Temperature Physics		
M. J. LAUBITZ	B.A.Sc. (Toronto), Ph.D. (Cantab.)	Senior Research Officer
P. J. KELLY	B.Sc. (Sir Geo. Williams), M.Sc., Ph.D. (Carleton)	Associate Research Officer

DIVISION OF PHYSICS—Continued

Name	*Degrees*	*Class Title*
High Temperature Physics—Concluded		
T. MATSUMURA	B.Sc., D.Sc. (Tohoku)	Associate Research Officer
J. G. COOK	B.Sc., M.Sc. (Brit. Col.), Ph.D. (Free U. Amsterdam)	Assistant Research Officer
Instrumental Optics		
P. D. CARMAN	B.A. (Toronto), M.Sc. (Rochester)	Senior Research Officer
H. BROWN	B.A., M.A., Ph.D. (Brit. Col.)	Associate Research Officer
Laser and Plasma Physics		
A. J. ALCOCK	B.A.Sc. (Toronto), Ph.D. (Oxon.)	Associate Research Officer
B. KRONAST	Dipl. Phys., Dr.rer.nat. (TH, Munich)	Associate Research Officer
M. C. RICHARDSON	B.Sc. (Imperial), A.R.C.S., Ph.D. (London)	Assistant Research Officer
K. BUCHL	Dipl. Phys., Dr.rer.nat. (TH, Munich)	Postdoctorate Fellow
A. M. GONDHALEKAR	B.Sc., Dipl. Adv. Sci., Ph.D. (Manchester)	Postdoctorate Fellow
Z. A. PIETRZYK	M.Sc. (Tech. U., Warsaw), Ph.D. (Pol. Acad. Sci.)	Postdoctorate Fellow
M. YA SHCHELEV	Dipl. Rad. Eng. (N. Bauman), Cand. Tech. Sci. (Phys. Tech. Inst. Moscow)	USSR Exchange Scientist
N. R. ISENOR	B.Sc. (Acadia), M.Sc. Ph.D. (McMaster)	Visiting Scientist
Mechanics		
E. GREEN	M.E. Cert. (Sheffield), B.Sc. (Carleton)	Senior Research Officer
G. S. K. WONG	M.Sc., Tech. Ph.D. (Manchester)	Assistant Research Officer
Metal Physics		
Z. S. BASINSKI	M.A., B.Sc., D.Phil., D.Sc. (Oxon.)	Principal Research Officer
I. M. TEMPLETON	M.A., D.Phil. (Oxon.), F. Inst. P.	Senior Research Officer
J.-P. JAN	L.ès Sc., Ph.D. (Lausanne)	Senior Research Officer
D. L. MARTIN	B.Sc., Ph.D. (London)	Senior Research Officer
P. J. JACKSON	B.Sc., B.Sc. (Hon.), Ph.D. (Witwatersrand)	Associate Research Officer
S. J. BASINSKI, (Mrs.)	M.A. (Oxon.)	Assistant Research Officer
S.-J. CHO	B.S., M.S. (Seoul), Ph.D. (Kentucky)	Assistant Research Officer
P. T. COLERIDGE	B.Sc., B.Sc. (Hon.) (Victoria), Ph.D. (Cantab.)	Assistant Research Officer
M. S. DUESBERY	M.A., Ph.D. (Cantab.)	Assistant Research Officer
R. A. FOXALL	B.Sc., A.R.S.M. (Imperial Coll.), Ph.D. (Cantab.)	Assistant Research Officer
R. TAYLOR	B.Sc. (Bishop's), Ph.D. (McMaster)	Assistant Research Officer
F. KLVANA	Dipl. Phys., RNDr. (Brno), CSc. (Caroline U. Prague)	Postdoctorate Fellow
C. M. PERROTT	B.Sc., B.Sc. (Hon.), Ph.D. (New England, Australia)	Postdoctorate Fellow
A. P. POGANY	B.Sc., M.B., B.S., Ph.D. (Melbourne)	Postdoctorate Fellow
G. B. SCOTT	B.Sc. (Glasgow), D.Phil. (Sussex)	Postdoctorate Fellow
R. PASCUAL	Lic. en Fis., D. Phys. (Cuyo U.)	IAEA Award
Optical Physics		
K. M. BAIRD	B.Sc. (New Bruns.), Ph.D. (Bristol)	Principal Research Officer
G. R. HANES	B.A., Ph.D. (Toronto)	Senior Research Officer
J. A. DOBROWOLSKI	B.Sc., M.Sc., Ph.D. (London)	Associate Research Officer
K. H. HART	B.Sc., M.Sc. (Alta.), Ph.D. (Toronto)	Associate Research Officer
H. D. RICCIUS	Dipl. Phys., Dr. rer nat. (Cologne)	Associate Research Officer
D. S. SMITH	B.Sc., M.Ac. (McGill)	Associate Research Officer
R. TURNER	B.A., D.Phil. (Oxford)	Associate Research Officer
K. J. SIEMSEN	Dr.-Ing. (Tech. U. Berlin)	Assistant Research Officer
K. C. SHOTTON	B.A., M.A., Ph.D. (Cambridge)	Postdoctorate Fellow

DIVISION OF PHYSICS—Continued

Name	*Degrees*	*Class Title*
Photogrammetric Research		
T. J. BLACHUT	Dipl. Ing. (Lwow)	Principal Research Officer
G. H. SCHUT	Dipl. Ing. (Delft)	Senior Research Officer
D. MAKOW	Dipl. El. Ing., Dr. Sc. Techn. (E.T.H. Zurich)	Senior Research Officer
Z. JAKSIC	Dipl. Ing. (Beograd)	Associate Research Officer
V. KRATKY	CSc (Brno)	Associate Research Officer
R. R. REAL	B.Sc. (Sask.), M.Eng. (McGill)	Associate Research Officer
J. H. SAASTAMOINEN	Dipl. Ing. (Helsinki)	Associate Research Officer
A. J. SMIALOWSKI	M.A.Sc. (Lwow)	Associate Research Officer
M. C. VAN WIJK	Dipl. Geod. Ing. (Delft)	Assistant Research Officer
H. ZIEMANN	Dipl. Ing. (Hanover)	Assistant Research Officer
J. SIMA	Ph.D. (Prague)	Postdoctorate Fellow
Radiation Optics		
G. W. WYSZECKI	Dipl. Ing., Dr. Ing. (Berlin), F.O.S.A.	Principal Research Officer
C. L. SANDERS	B.A.Sc. (Toronto), Ph.D. (London)	Senior Research Officer
H. W. BUDDE	Dipl. Phys. (Freie, Berlin)	Associate Research Officer
A. R. ROBERTSON	B.Sc., A.R.C.S. (London), Ph.D., D.I.C. (Imperial Coll.)	Assistant Research Officer
H. W. WRIGHT	B.Sc. (Bishop's), M.Sc. (Carleton)	Assistant Research Officer
Spectroscopy		
G. HERZBERG	M.A. (Sask.), Dr. Ing. (Darmstadt), LL.D. (Sask., Toronto, Dalhousie, Alta.), D.Sc. (Oxon., McMaster, Brit. Col., Queen's, New Bruns., Nat. Univ. Ireland, Chicago, Carleton, Memorial, York, Windsor), Fil. Hed. Dr. (Stockholm), Dr. rer. nat. h.c. (Göttingen), F.R.S.C., F.R.S., C.C.	Distinguished Research Scientist
A. E. DOUGLAS	B.A., M.A. (Sask.), Ph.D. (Penn. State), F.R.S.C., F.R.S.	Director
D. A. RAMSAY	B.A., M.A., Ph.D. (Cantab.), F.A.P.S., F.R.S.C.	Principal Research Officer
C. C. COSTAIN	B.A., B.A. (Hon.), M.A. (Sask.), Ph.D. (Cantab.)	Senior Research Officer
H. LEW	B.A. (Brit. Col.), M.A. (Toronto), Ph.D. (Mass. Inst. Tech.)	Senior Research Officer
K. P. HUBER	Ph.D. (Basel)	Associate Research Officer
J. W. C. JOHNS	B.A., D. Phil. (Oxon.)	Associate Research Officer
T. OKA	B.Sc., M.Sc., D.Sc. (Tokyo)	Associate Research Officer
P. R. BUNKER	B.Sc. (London), Ph.D. (Cantab.)	Assistant Research Officer
G. D. CHAPMAN	B.Sc. (Assumption), M.Sc., Ph.D. (Windsor)	Assistant Research Officer
J. BILLINGSLEY	B.A., Ph.D. (Cambridge)	Postdoctorate Fellow
G. N. CURRIE	B.Sc. (Edinburgh), Ph.D. (Cambridge)	Postdoctorate Fellow
S. M. JAPAR	B.S. (City Coll. of N.Y.), Ph.D. (Case Western Res.)	Postdoctorate Fellow
C. JUNGEN	D. Phil. (Basel)	Postdoctorate Fellow
B. L. LUTZ	B.Sc. (Lebanon Valley), A.M., Ph.D. (Princeton)	Postdoctorate Fellow
T. SHIMIZU	B.A., M.Sc., Ph.D. (Tokyo)	Postdoctorate Fellow
J. M. R. STONE	B.Sc., Ph.D. (Reading)	Postdoctorate Fellow
G. F. WINNEWISSER	Dipl. Phys., (Karlsruhe), Ph.D. (Duke)	Canada Council Fellow
M. HORANI	L. ès S., D. ès S. (Paris)	NATA Fellow
H. MEINEL	B.Sc., M.Sc., Ph.D. (Munich)	Visiting Scientist
F. SHIMIZU (Mrs.)	B.A., M.Sc., Ph.D. (Tokyo)	
Theoretical Physics		
S. SHANMUGADHASAN	B.Sc., M.Sc. (London), Ph.D. (Cantab.)	Assistant Research Officer

DIVISION OF PHYSICS—Concluded

Name	*Degrees*	*Class Title*
X-Rays and Nuclear Radiations		
K. W. GEIGER	Dipl. Phys. (Tubingen), Dr.rer.nat. (Mainz)	Senior Research Officer
A. P. BAERG	B.Sc., Ph.D. (McGill)	Senior Research Officer
W. H. HENRY	B.Sc., (Queen's), Ph.D. (McGill)	Senior Research Officer
K. H. LOKAN	B.Sc., Ph.D. (Aust. Nat. Univ.)	Senior Research Officer
R. J. ADAMS	B.Sc., M.Sc. (London), Ph.D. (Brit. Col.)	Associate Research Officer
W. R. DIXON	B.A., M.A. (Sask.), Ph.D. (Queen's)	Associate Research Officer
H. A. GILLIS	B.Sc. (St. Francis Xavier), Ph.D. (Notre, Dame, Indianna)	Associate Research Officer
N. V. KLASSEN	B.Sc., Ph.D. (McGill)	Associate Research Officer
J. J. H. PARK	B.Sc. (Yonsei), Ph.D. (Edinburgh)	Associate Research Officer
N. K. SHERMAN	Ph.D. (Queen's)	Associate Research Officer
R. S. STOREY	B.A., M.A. (Queen's), Ph.D. (Glasgow)	Associate Research Officer
L. VAN DER ZWAN	B.Sc., M.Sc. (Dalhousie), Ph.D. (Virginia)	Associate Research Officer
R. W. GELLIE	Ph.D. (Melbourne)	Assistant Research Officer
R. LEVESQUE	B.Sc.A., M.Sc. (Laval)	Assistant Research Officer
G. G. TEATHER	M.A.Sc. (Brit. Col.)	Junior Research Officer
T. D. MACMAHON	B.Sc. (Queen's, Belfast), Ph.D. (Strathclyde, Glasgow)	Postdoctorate Fellow

RADIO AND ELECTRICAL ENGINEERING DIVISION

Director's Office		
W. A. CUMMING	B.Sc. (Queen's)	Director
J. L. LOCKE	B.A., M.A., Ph.D. (Toronto) F.R.S.C.	Associate Director
M. CARTER (Mrs.)		Administrative Assistant
Antenna Engineering		
W. A. CUMMING	B.Sc. (Queen's)	Director
W. LAVRENCH	B.Sc., M.Sc. (Queen's)	Senior Research Officer
G. C. MCCORMICK	B.Sc. (Dalhousie), M.Sc. (Acadia), Ph.D. (McGill)	Senior Research Officer
J. Y. WONG	B.Sc. (Manitoba), M.Sc., Ph.D. (Illinois)	Senior Research Officer
R. A. HURD	B.A., M.A. (Toronto)	Associate Research Officer
E. V. JULL	B.Sc. (Queen's), Ph.D. (London)	Associate Research Officer
R. F. MILLAR	B.A., M.A. (Toronto), Ph.D. (Cambridge)	Associate Research Officer
A. L. VANKOUGHNETT	B.E.Sc. (Western Ont.), M.A.Sc., Ph.D. (Toronto)	Assistant Research Officer
W. WYSLOUZIL	B.Eng. (Carleton)	Assistant Research Officer
Data Systems		
F. V. CAIRNS	B.A.Sc. (Brit. Col.), M.A.Sc. (Toronto)	Senior Research Officer
E. L. R. WEBB	B. Eng. (McGill)	Senior Research Officer
S. G. JONES	B.Sc. (Alta.), M.Sc. (Stanford)	Senior Research Officer
H. LECAINE	B.Sc., M.Sc. (Queen's), Ph.D. (Birmingham)	Senior Research Officer
J. K. PULFER	B.Sc., M.Sc. (Manitoba)	Senior Research Officer
A. STANIFORTH	B.A.Sc. (Brit. Col.)	Senior Research Officer
N. BURTNYK	B.Sc. (Manitoba)	Associate Research Officer
T. H. SHEPERTYCKI	B.Sc. (Manitoba)	Associate Research Officer
K. A. STEELE	B.Sc. (Manitoba)	Associate Research Officer
M. ITO	B.Sc., M.Sc. (Manitoba)	Assistant Research Officer
D. H. O'HARA	B.Sc., M.Sc. (Queen's)	Assistant Research Officer
S. TAVARES	B.Eng. (McGill), M.S. (Cal. Tech), Ph.D. (McGill)	Assistant Research Officer
M. WEIN	B.Eng., M.Sc., Ph.D. (McGill)	Assistant Research Officer
J. L. WOLFE	B.Sc. (Queen's)	Assistant Research Officer

RADIO AND ELECTRICAL ENGINEERING DIVISION—Continued

Name	*Degrees*	*Class Title*
Electrical Engineering		
N. L. KUSTERS	M.E. (Louvain), S.M. (M.I.T.)	Principal Research Officer
J. H. SIMPSON	B.Eng. (McGill), Ph.D. (Bristol)	Principal Research Officer
F. C. CREED	B.Sc. (Queen's), Ph.D. (London)	Senior Research Officer
F. R. LIPSETT	B.A.Sc., M.A.Sc. (Brit. Col.), Ph.D. (London)	Senior Research Officer
W. J. M. MOORE	B.A.Sc. (Brit. Col.), M.Eng. (McGill)	Senior Research Officer
R. M. MORRIS	B.A. (Mt. Allison), B.E. (N.S. Tech.), S.M. (Mass. Inst. Tech.)	Senior Research Officer
J. ROLFE	B.Sc., Ph.D. (London)	Senior Research Officer
M. M. C. COLLINS	B.Sc., M.Sc. (Alta.), Ph.D. (Liverpool)	Associate Research Officer
M. P. MACMARTIN	B.Sc. (Queen's)	Associate Research Officer
A. R. MORSE	B.Sc.. (Manitoba)	Associate Research Officer
R. J. DENSLEY	B.Sc., Ph.D. (London)	Assistant Research Officer
D. H. GOODE	B.Sc., M.Sc., Ph.D. (Canterbury)	Assistant Research Officer
M. IKEZAWA	B.Sc., M.Sc., D.Sc. (Tohoku)	Postdoctorate Fellow
Electron Phyiscs		
J. P. HOBSON	B.A.Sc., M.A.Sc. (Brit. Col.), Ph.D. (Calif.)	Senior Research Officer
E. V. KORNELSEN	B.Eng., M.Sc. (Sask.), Ph.D. (McGill)	Senior Research Officer
R. A. ARMSTRONG	B.A. (Toronto), M.Sc., Ph.D. (McGill)	Associate Research Officer
A. SZABO	B.Sc. (Queen's), M.Sc. (McGill)	Associate Research Officer
L. E. ERICKSON	B.Sc. (Queen's), S.M., Ph.D. (Chicago)	Assistant Research Officer
B. R. WILLIAMS	B.Sc., Ph.D. (North Wales)	Assistant Research Officer
Engineering Design		
R. D. HARRISON	B.Sc. (McGill)	Senior Research Officer
J. C. BARNES	B.A.Sc., M.A.Sc. (Toronto)	Senior Research Officer
Z. MORDASEWICZ	Mech. Eng. (Warsaw)	Assistant Research Officer
Information Science		
W. C. BROWN	B. Eng. (McGill)	Principal Research Officer
C. R. CLEMENCE	B.Sc. (Manitoba)	Senior Research Officer
W. G. HOYLE	B.Sc. (Alta.), M.Sc. (McGill)	Senior Research Officer
F. R. HUNT	B.Sc., M.Sc., Ph.D. (Western Ont.)	Senior Research Officer
E. F. V. ROBINSON	B.Sc. (Alta.)	Senior Research Officer
J. W. BRAHAN	B.A.Sc. (Brit. Col.)	Associate Research Officer
A. HENDRY	B.Sc. (Queen's), M.Sc. (Carleton)	Associate Research Officer
J. HUMPHRIES	B.A.Sc. (Toronto)	Associate Research Officer
J. R. KENNEY	B.Sc., M.Sc. (Queen's)	Associate Research Officer
J. E. FISHER	B.Sc., Ph.D. (London)	Assistant Research Officer
A. M. HLADY	B.Sc. (Manitoba), M.A.Sc. (Toronto)	Assistant Research Officer
Instrument		
C. F. PATTENSON	B.Sc. (Alta.)	Senior Research Officer
J. A. HOPPS	B.Sc. (Manitoba)	Senior Research Officer
A. C. HUDSON	B.A.Sc. (Toronto)	Senior Research Officer
R. F. CLARK	B.Sc. (Alta.), M.Sc. (Stanford)	Associate Research Officer
A. P. JURKUS	B.A.Sc. (Polytech.), Ph.D. (Sheffield)	Associate Research Officer
O. Z. ROY	B.Sc. (Manitoba), M.Sc. (McGill)	Associate Research Officer
G. T. SCHULER	M.D., C.M. (Queen's)	Associate Research Officer
J. C. SWAIL	B.Sc. (McGill)	Assistant Research Officer
Navigational Aids		
H. R. SMYTH	M.B.E., B.Eng. (McGill)	Principal Research Officer
A. D. HOOD	B.A.Sc. (Toronto)	Senior Research Officer
K. AYUKAWA	B.Sc. (Manitoba)	Associate Research Officer
L. G. COX	B.Sc. (Western Ontario)	Associate Research Officer
G. NEAL	B.Sc. (Queen's)	Associate Research Officer

RADIO AND ELECTRICAL ENGINEERING DIVISION—Concluded

Name	*Degrees*	*Class Title*
Model Shops		
W. B. JOHNSON		Superintendent
Reports and Publications		
E. I. SWAIL (Mrs.)	B.Sc. (McGill)	Information Officer

ASTROPHYSICS BRANCH

Chief's Office		
J. L. LOCKE	B.A., M.A., Ph.D. (Toronto) F.R.S.C.	Associate Director and Chief of Branch
Algonquin Radio Observatory		
R. F. DUSTON	B. Eng. (McGill)	Research Council Officer
A. G. FINDLAY		Technical Officer
Dominion Astrophysical Observatory (Victoria, B.C.)		
K. O. WRIGHT	B.A., M.A. (Toronto), Ph.D. (Michigan), F.R.S.C.	Principal Research Officer
G. A. BREALEY	B.A.Sc., M.A.Sc. (Brit. Col.)	Senior Research Officer
G. J. ODGERS	B.A., M.A. (Melbourne), M.Sc. (Cantab.), Ph.D. (California)	Senior Research Officer
E. H. RICHARDSON	B.A., M.A. (Brit. Col.), Ph.D. (Toronto)	Senior Research Officer
A. H. BATTEN	B.Sc. (St. Andrews), Ph.D. (Manchester)	Associate Research Officer
E. B. F. BROSTERHUS	B.A. (Freiburg), M.A., Ph.D. (Hamburg)	Associate Research Officer
D. H. ANDREWS	B.A. (Brit. Col.)	Associate Research Officer
D. CRAMPTON	B.Sc., M.A., Ph.D. (Toronto)	Assistant Research Officer
J. M. FLETCHER	B.Sc. (Brit. Col.), M.A. (Toronto)	Assistant Research Officer
G. HILL	B.Sc. (Auckland), M.A. (Minnesota), Ph.D. (Texas)	Assistant Research Officer
J. B. HUTCHINGS	B.Sc., M.Sc. (Witwatersrand), Ph.D. (Cantab.)	Assistant Research Officer
E. K. LEE	B.A. (Western Ont.), M.S. (Michigan)	Assistant Research Officer
S. C. MORRIS	B.Sc. (Brit. Col.), M.A., Ph.D. (Toronto)	Associate Research Officer
D. C. ELLIS	B.Sc. (Toronto)	Assistant Research Officer
C. L. MORBEY	B.Sc., M.Sc. (Carleton)	Assistant Research Officer
G. C. AIKMAN	B.Sc. (Bishop), M.Sc. (Toronto)	Junior Research Officer
P. F. YOUNGER	B.A., M.A. (Kansas)	Assistant Research Officer
J. GRYGAR	Dipl. Phys., R.N.Dr. (Charles), C.Sc. Astronomy (Czech. Acad. of Science)	Postdoctorate Fellow
Dominion Radio Astrophysical Observatory (Pentiction, B.C.)		
J. A. GALT	B.A., M.A., Ph.D. (Toronto)	Senior Research Officer
P. E. ARGYLE	B.A., M.A., Ph.D. (Brit. Col.)	Associate Research Officer
C. H. COSTAIN	B.A., M.A. (Sask.) Ph.D. (Cantab.)	Associate Research Officer
J. D. LACEY	B.A.Sc., M.A.Sc. (Toronto)	Associate Research Officer
R. S. ROGER	B.A.Sc. (Brit. Col.), Ph.D. (Manchester)	Associate Research Officer
Radio Astronomy		
J. L. LOCKE	B.A., M.A., Ph.D. (Toronto), F.R.S.C.	Chief of Branch
C. W. MCLEISH	B.A.Sc. (Brit. Col.), M.Sc. (Cal. Tech.)	Principal Research Officer
N. W. BROTEN	B.Sc. (Western Ont.)	Senior Research Officer
A. E. COVINGTON	B.A., M.A. (Brit. Col.)	Senior Research Officer
L. H. DOHERTY	B.Eng. (McGill), Ph.D. (Cornell)	Senior Research Officer
W. J. MEDD	B.A., B.Sc. (Alta.)	Senior Research Officer
R. S. RICHARDS	B.A., M.A. (Oxon)	Senior Research Officer
G. EVANS	B.Sc. (London)	Associate Research Officer
V. GAIZAUSKAS	B.A., M.A., Ph.D. (Toronto)	Associate Research Officer
L. A. HIGGS	B.Sc. (N.B.), D. Phil. (Oxon)	Associate Research Officer

ASTROPHYSICS BRANCH—Concluded

Name	*Degrees*	*Class Title*
Radio Astronomy—Concluded		
T. H. LEGG	B.A.Sc. (Brit. Col.), M.Sc., Ph.D. (McGill)	Associate Research Officer
J. M. MACLEOD	B.Sc. (Alta.), M.S., Ph.D. (Illinois)	Associate Research Officer
L. R. MCNARRY	B.Sc., M.Sc (Western Ont.)	Associate Research Officer
S. A. STONE	B.Sc. (Manitoba), M.Sc. (McGill)	Associate Research Officer
B. H. ANDREW	B.Sc. (Glasgow), Ph.D. (Cambridge)	Assistant Research Officer
L. AVERY	B.A.Sc. (Toronto), Ph.D. (Colorado)	Assistant Research Officer
M. B. BELL	B.Sc., M.Sc. (Western Ont.)	Assistant Research Officer
G. A. HARVEY (Mrs.)	B.A., M.A. (McMaster)	Assistant Research Officer
J. B. RICE	B.A. (Western Ont.), M.A. (Toronto), Ph.D. (Western Ont.)	Postdoctorate Fellow
Upper Atmosphere Research		
P. M. MILLMAN	B.A. (Toronto), M.A., Ph.D. (Harvard), F.R.S.C.	Principal Research Officer
I. HALLIDAY	B.A., M.A., Ph.D. (Toronto)	Senior Research Officer
A. V. JONES	B.Sc., M.Sc. (Canterbury), Ph.D. (Cambridge)	Senior Research Officer
B. A. MCINTOSH	B.Sc., M.Sc., (Western Ont.), Ph.D. (McGill)	Senior Research Officer
A. G. MCNAMARA	B.Sc., M.Sc., Ph.D. (Sask.)	Senior Research Officer
M. J. NEALE	B.Sc. (Manitoba)	Senior Research Officer
R. L. GATTINGER	B.E., M.Sc., Ph.D. (Sask.)	Associate Research Officer
A. A. GRIFFIN	B.A. (Toronto)	Associate Research Officer
M. D. WATSON	B.Sc., M.Sc., Ph.D. (Western Ont.)	Associate Research Officer
*A. T. BLACKWELL	B.Sc. (Western Ont.), M.Sc. (Queen's)	Assistant Research Officer
J. M. GRANT	B.A. (Toronto)	Assistant Research Officer
D. R. MCDIARMID	B.A.Sc., M.A.Sc., Ph.D. (Brit. Col.)	Assistant Research Officer
R. WLOCHOWICZ	B.Eng. (McGill)	Assistant Research Officer

SPACE RESEARCH FACILITIES BRANCH

J. F. AITKEN	B.Sc. (Alta.)	Chief Administrative Officer
A. D. ARMSTRONG	B.A. (Carleton), M.A. (Ottawa), M.P.A. (Syracuse)	
Range Section		
Z. R. CHARKO		Section Head
G. O. BERRINGER		Technical Officer
J. A. TARZWELL	B.Sc. (Queen's), M.S.E. (Michigan)	Research Council Officer
N. HUSSAIN		Technical Officer
Research Support Section		
P. DE L. MARKHAM		Section Head
H. ROBERTS	B.A.Sc. (Ottawa)	Research Council Officer
A. J. LAFLECHE	B.A. (Montreal)	Technical Officer
P. E. TOWNSEND		Technical Officer
Data and Reports Section		
J. H. CRAVEN	B.A.Sc. (Brit. Col.), M.A.Sc. (Toronto)	Section Head
W. H. WATERS		Reports Officer
CAPT. E. W. RANCE[1]		Data Officer
Churchill Research Range		
T. W. MCGRATH	B.Sc. (St. Francis Xavier)	General Superintendent
F. CREUTZBERG	B.Sc., M.Sc. (Melbourne), Ph.D. (University College)	Associate Research Officer
F. R. HARRIS	B.Sc. (Queen's), M.Sc., Ph.D. (Sask.)	Assistant Research Officer

* In charge of Meteorite Observation and Recovery Project, Saskatoon.
[1] Seconded from the Canadian Armed Forces.

SPACE RESEARCH FACILITIES BRANCH—Concluded

Name	*Degrees*	*Class Title*
Churchill Research Range—Concluded		
D. A. FRETTS	B.A. (Queen's), M.Sc., (USAF Inst. of Tech.)	Chief of Plans and Operations
R. G. BROWN	B.Sc. (Toronto)	Assistant Operations Officer
J. P. WORTH		Range Safety Officer
R. D. HENDRY	B.Sc. (Aberdeen)	Systems Engineering Officer

LONDON OFFICE

W. L. HANEY	B.A. (Manitoba), P.Eng., M.E.I.C., A.F.C.A.S.I., Sen.M.I.E.E.E.	Chief Scientific Liaison Officer
N. A. SMITH	C.D., C.Eng., M.I.Mar.E., A.F.C.A.S.I.	Scientific Liaison Officer

SUMMARY OF STAFF STATISTICS - 1 APRIL 1970

Total Staff Classified by Division or Branch, and by Category

(Postdoctorate Fellows included)

Division or Branch	Scientific Personnel	Technical Personnel	Admin. & Oper'l Personnel	Total
NRC Laboratories				
Atlantic Regional Laboratory	34	20	12	66
Biochemistry	52	21	4	77
Biology	42	51	12	105
Building Research	80	83	65	228
Chemistry	116	83	19	218
Mechanical Engineering	70	234	40	344
National Aeronautical Establishment	73	139	22	234
Prairie Regional Laboratory	32	38	14	84
Physics	133	150	23	306
Radio & Electrical Engineering	126	223	56	405
Space Research Facilities Branch	13	8	10	31
Total	771	1050	277	2098
Industrial Research Assistance	31	1	16	48
University Support	5	—	28	33
Services				
Administration & Executive Offices	10	4	182	196
Administrative Planning	2	—	2	4
Canadian Journals of Research	4	1	16	21
Canadian Patents & Development Limited	9	—	14	23
Computation Centre	19	—	25	44
Financial Services	1	—	25	26
Information Services	1	2	14	17
International Relations	4	—	3	7
London Liaison Office	2	—	4	6
National Science Library	5	—	96	101
Plant Engineering	10	23	236	269
Program Studies	4	—	3	7
Total	71	30	620	721
TOTAL	878	1081	941	2900

University Graduates Engaged in Scientific Research, Classified by Senior Degree Held and by Course

(Postdoctorate Fellows included)

Course	Bachelors	Masters	Doctors	Total
Biological Sciences	3	7	73	83
Engineering and Architecture	85	98	70	253
Physical Sciences:				
Chemistry	19	14	159	192
Mathematics and Physics	16	30	138	184
Other	3	9	19	31
General and Pass Sciences	5	—	—	5
Non-Scientific	1	—	1	2
TOTAL	132	158	460	750

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